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ABSTRACT

The Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package to assist Navy Equipment Operators First and Chief in fulfilling the requirements of their rating. (Navy Equipment Operators First and Chief direct and coordinate efforts of individuals and crews in construction, earthmoving, roadbuilding, quarrying, and well drilling assignments: maintain records and reports on mobile and stationary equipment: and supervise and administer automotive and construction equipment pools.) Designed for individual study and not formal classroom instruction, this manual provides subject matter that relates directly to the occupational standards of the Equipment Operator rating. The subject matter is divided into the following nine chapters: (1) Administration: (2) Techniques of Supervision: (3) Advanced Based Planning, Embarkation, and Project Turnover: (4) Construction Scheduling: (5) Grading, Soil Stabilization, and Road Surfacing: (6) Pits and Quarries: (7) Well Drilling: (8) Construction and Automotive Equipment Pool Management: and (9) Miscellaneous Construction Equipment. Assignments in each chapter involve learning objectives and supporting items designed to lead the student through the course. (BM)

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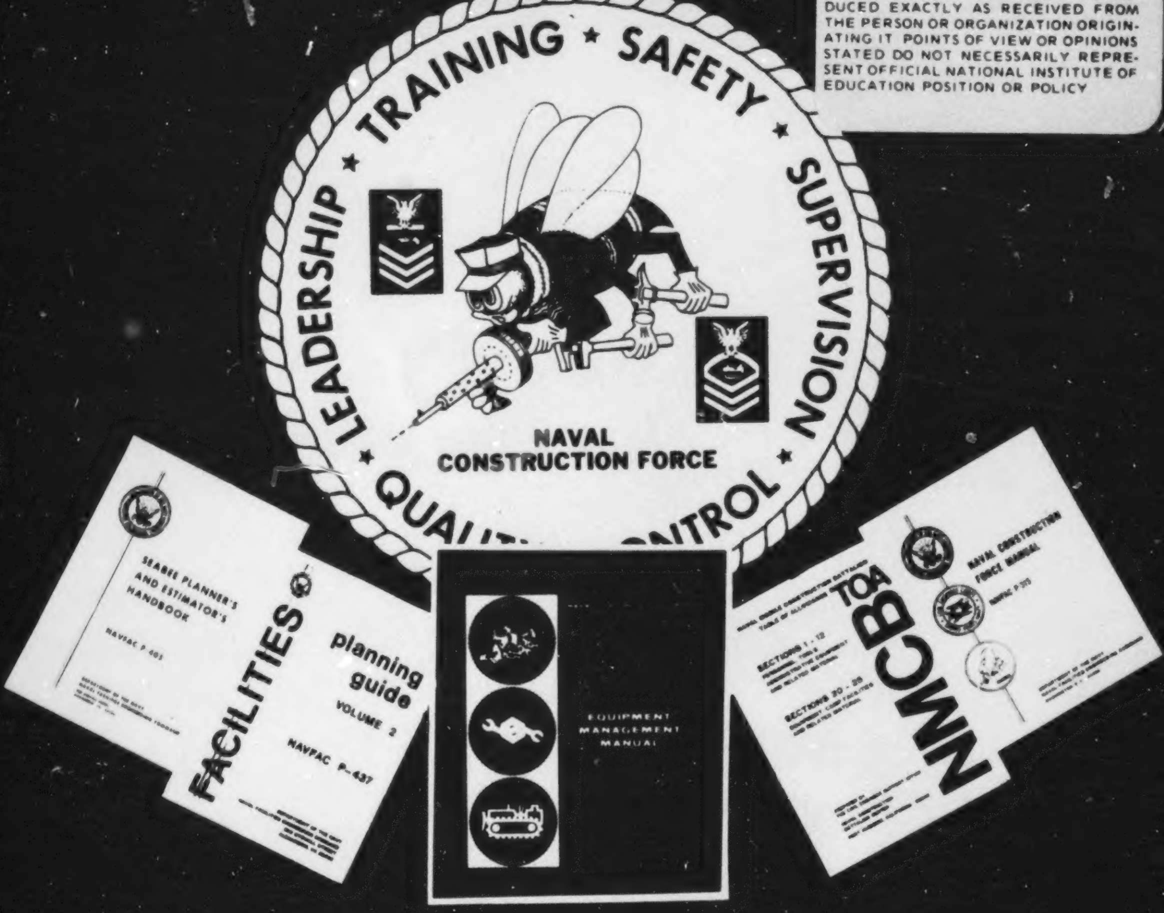
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NAVAL EDUCATION AND TRAINING COMMAND
RATE TRAINING MANUAL AND NONRESIDENT CAREER COURSE

NAVEDTRA 10641-G

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Although the words "he", "him", and "his", are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Equipment Operator 1 & C,* NAVEDTRA 10641-G.

PREFACE

The ultimate purpose of training Naval personnel is to produce a combatant Navy which can insure victory at sea. A consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable Equipment Operators First and Chief help themselves fulfill the requirements of their rating. They direct and coordinate efforts of individuals and crews in execution of construction, earthmoving, roadbuilding, quarrying, and well drilling assignments; maintain records and reports on mobile and stationary equipment; and supervise and administer automotive and construction equipment pools.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the occupational standards of the Equipment Operator rating. The NRCC provides a way of satisfying the requirements for completing the RTM. Assignments in the NRCC include learning objectives and supporting items designed to lead the student through the RTM.

This RTM/NRCC was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Naval Facilities Engineering Command, Alexandria, Virginia, the Naval Construction Training Center, Port Hueneme, California, the Naval Construction Training Center, Gulfport, Mississippi, and the Civil Engineering Support Office, Port Hueneme, California.

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1

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CREDITS

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CHAPTER 1

ADMINISTRATION

As an EO1 or EOC, you will have many responsibilities added to those which you had at second class level. You have acquired a lot of valuable knowledge and now it is your turn to pass on the technical know-how of your job to others. In addition to supervising and training lower rated personnel, you must be able to perform various administrative duties–such as planning, estimating, and inspecting construction work. This chapter provides information that you will use in planning jobs to be done in the shop or field, preparing estimates for construction projects, administering a company accident prevention program, inspecting structures and work areas, and training personnel in technical and general military subjects. A brief treatment is also presented on materials and equipment, records and reports, and official Navy correspondence.

HINTS ON PLANNING

Planning is the process of determining requirements and devising and developing methods and schemes of action for construction of a project. In addition to day-to-day planning, the following primary matters should be considered in construction planning: work element estimates, material estimates, equipment estimates, manpower estimates, plant layout, material delivery and storage, work schedules, and progress control. These considerations are more or less dependent upon each other and all are taken into account in any well-planned project. The success of any project depends to a great extent upon the amount of detail and the care taken in planning it.

Proper planning saves time and money for the Navy, and makes the work easier and more pleasant for your whole group. It can eliminate friction, jealousy, and confusion, and it can free you from many of the details of the work, thus giving you time to carry out other important duties. Proper planning expedites the work and eliminates "bottlenecking," (remember that the neck of the bottle is always at its top), and, most important to you personally, it makes your job easier.

As the petty officer in charge of a crew, you are responsible for the time of your crewmembers as well as for your own time. You must plan so that they will be kept busy doing constructive work. This will be to your convenience, and a point to remember is: PLAN AHEAD. Having the crewmembers stand around idle each morning while you plan obviously would be a waste of manpower. At the close of each day, you should confirm planning for the next workday. In doing so, carefully consider factors that have a bearing on the availability and use of manpower, equipment, and supplies. For effective planning, you may need answers to various questions, such as those listed below.

1. Manpower. Who is to do what? How is it to be done? When is it to be finished? Knowing that idleness may breed discontent, have you arranged to have another job ready for starting as soon as the first one is finished? Is every crewmember fully utilized?
2. Equipment. Are all necessary tools and equipment on hand to do the job? Is safety equipment on hand?
3. Supplies. Are all necessary supplies on hand to start the job? If not, who should take action?

8

Have a definite work schedule and inspection plan. Set up goals or quotas for the day. Have a definite plan for personally checking at intervals to see that the work is being accomplished and that the goals are going to be met. Spot check for accuracy, workmanship, and the need for training.

EO's must be trained to do a variety of jobs by means of the rotation method, on-the-job training, or classroom work; allow time for this in your planning for a job. Time must also be allowed for handling personnel problems, records, and military duties. As a supervisor, you must allow time for reports and other paperwork which is necessary for the control of personnel and materials under your charge.

Until you learn to delegate work, you can never be much of a success. In delegating authority, be sure that the personnel concerned have the training and information necessary to carry out the work. If you find that they cannot do the jobs that are required, they may have to be retrained. Remember, you can delegate authority—within reason—to subordinates, but you cannot delegate your responsibility for the final product.

ESTIMATING

Estimating is the act of determining the size of the job, the kind of work to be performed, and the quantities of work elements, materials, labor and equipment needed to perform this work. Estimating is an important part of planning for jobs and/or projects. If you like working with figures, the preparation of estimates should be interesting work. In addition to a knowledge of arithmetic, however, an estimator should possess a number of other qualifications, some of which are noted below.

As an estimator, you should be able to mentally picture the separate operations of the job as the work will progress through the various stages of construction. You must have previous construction experience and be able to do careful and accurate work free of errors. You must also use good judgment when determining what effect numerous factors and conditions will have on construction of the project and what allowances should be made for each of them. Have available information about materials, equipment, and labor required to perform various types of work under conditions you can expect to encounter in accomplishing construction projects. Collection of such information on construction performance is part of the job of estimating. Reference information of this kind may change from time to time, and therefore should be revised frequently. Working individually or as a member of a team, you may often be required to plan construction and prepare estimates for other construction ratings. So, in addition to knowing your own specialty, you should have a working knowledge of others.

Remember that various procedures are used in estimating for construction work, and those described here are suggested procedures rather than standard procedures. You must decide whether or not a procedure can be applied effectively and, in some cases, revise the procedure to make it more suitable to the particular project being estimated.

USE OF DRAWINGS AND SPECIFICATIONS

Information provided on drawings is a main basis for measuring quantities of work elements and materials. Accurate estimating requires a thorough examination of the drawings. All notes and references should be read carefully and all detail and reference drawings should be examined. Dimensions shown on drawings and/or figured dimensions should be used in preference to scaled dimensions. If it becomes necessary to scale dimensions on drawings, a scale rule should be used and the graphic scale on the drawings should be checked for expansion or shrinkage. When there is disagreement between the plans, elevations, and details, the detail drawing should normally be followed unless it is obviously wrong.

The specifications should be used together with the drawings when making quantity estimates. When there is disagreement between the specifications and the drawings, the specifications should normally be followed. If in doubt, consult the OICC, Operations Officer, or PW Officer for a decision. The estimator should become thoroughly familiar with all the requirements stated in the specifications. Some estimators will have to read the specifications more than once in order to fix these requirements in their minds. Notes made while reading the specifications will prove helpful when examining the drawings. These notes should list items of work or material which are unusual, items not familiar to the estimator, and reminders for use during examination of the plans.

RECORD DRAWINGS
(As-Built Drawings)

Record drawings provide a permanent record of As-Built conditions upon completion (or termination before completion) of the construction work on a project.

As-Built drawings consist of the original construction drawings, corrected to show additions, omissions, or changes made during construction. Changes made on the original construction drawing are drawn in red on the working drawing. The drawing is then turned into Engineering, where the final record drawing is completed.

NEED FOR ACCURACY

Quantity estimates are used as a basis for purchasing materials and for determining equipment and manpower requirements. They are also used in scheduling progress, which provides the basis for scheduling material deliveries, equipment and manpower. In view of the widespread use, you can see that accuracy in preparing quantity estimates is very important. To help insure accuracy, quantity estimates should be checked in a manner that will eliminate as many errors as possible. One of the best ways to check a quantity estimate is to have another person make an independent estimate, then compare the two estimates after both are completed.

WORK ELEMENT ESTIMATES

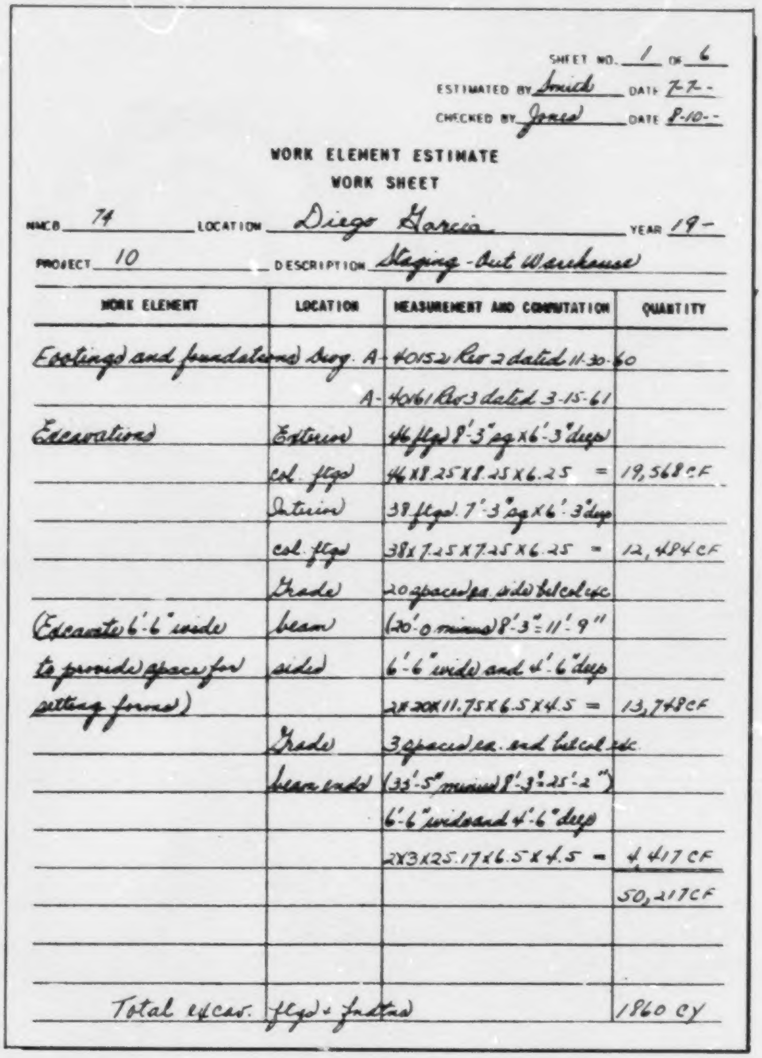
A work element estimate is a listing of the quantities of each work element (such as volume of fill to be hauled) required to construct a given project. Work element estimates are prepared by computing the quantities of the various items of work shown or referenced by notes on the drawings and described in the specifications. You may sometimes hear work element estimates called Quantity Surveys or Quantity Takeoffs. They are used in scheduling progress, which provides the basis for scheduling material deliveries, equipment and manpower. Errors in work element estimates can multiply many times through their use in the preparation of these other estimates and schedules.

In estimating, you should have a good general knowledge of the project to be constructed, before performing any actual takeoff of quantities. You can obtain this knowledge by studying the drawings, reading the specifications, and examining all available information about the project site and local conditions. After becoming familiar with the project, you are ready to begin measuring and recording quantities of materials for the work elements.

The normal practice of measuring quantities is to begin by measuring work elements on the foundation and footing plan and to proceed through the basement and each succeeding floor plan of the architectural and structural drawings. All reference and detail drawings that refer to a particular plan are examined and worked in conjunction with that plan. After examination of the plans, the elevations and then the details are examined one by one, and all materials not previously taken off are measured and recorded. Often concrete, reinforcing, and structural features are shown on drawings separate from the architectural features. When this is done, it is best to work the concrete and reinforcing drawings first, followed by the structural and then the architectural drawings. After completing the architectural and structural drawings, follow up with the mechanical and electrical drawings and then available specialty or shop drawings.

When measuring quantities on a drawing, it is better to begin at one side and work towards the opposite side, marking with a colored pencil the particular work as it is measured and recorded. Work items, such as cut, fill, concrete, and reinforcing, can be marked with a simple check (✓), but conduit and piping should be marked by tracing over the part measured with a colored pencil. The colored marks not only show you what has been taken off, thus preventing duplication, but provide a means of checking a drawing for omissions.

As each work element is measured, record information and show computations on a worksheet. Figure 1-1 illustrates the type of information shown on a typical work element estimate worksheet. The heading of each worksheet should show the following: that it is a work element estimate worksheet, the worksheet number, estimator's name, date of takeoff, checker's name, date checked, battalion



SHEET NO. 1 OF 6
ESTIMATED BY Smith DATE 7-7-
CHECKED BY Jones DATE 8-10--

WORK ELEMENT ESTIMATE
WORK SHEET

NMCB 74 LOCATION Diego Garcia YEAR 19-
PROJECT 10 DESCRIPTION Staging-Out Warehouse

WORK ELEMENT	LOCATION	MEASUREMENT AND COMPUTATION	QUANTITY
Footings and foundations	Dwg. A-	40152 Rev 2 dated 11-30-60	
	A-	40161 Rev 3 dated 3-15-61	
Excavations	Exterior	46 ftgs 8'-3" sq x 6'-3" deep	
	col. ftgs	46 X 8.25 X 8.25 X 6.25 =	19,568 CF
	Interior	38 ftgs. 7'-3" sq x 6'-3" deep	
	col. ftgs	38 x 7.25 X 7.25 X 6.25 =	12,484 CF
	Grade	20 spaces ea. side bet col etc	
(Excavate 6'-6" wide	beam	(20'-0 minus 8'-3" = 11'-9"	
to provide space for	sides	6'-6" wide and 4'-6" deep	
setting forms)		2 x 20 x 11.75 x 6.5 x 4.5 =	13,748 CF
	Grade	3 spaces ea. end bet col etc	
	beam ends	(35'-5" minus 8'-3" = 25'-2")	
		6'-6" wide and 4'-6" deep	
		2 X 3 X 25.17 X 6.5 X 4.5 =	4,417 CF
			50,217 CF
Total excav.	ftgs + fndtns		1860 CY

87.1

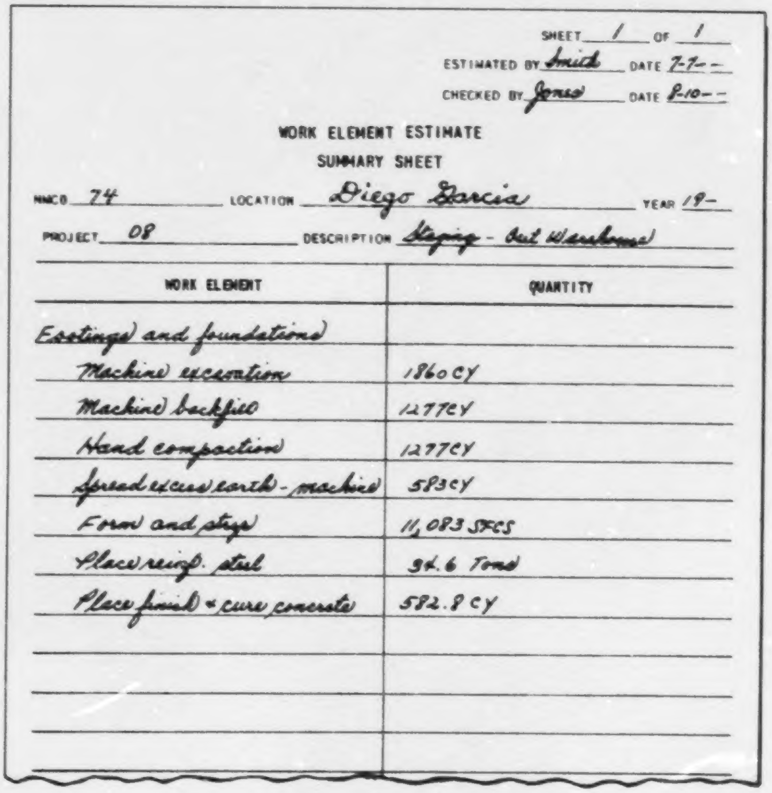
Figure 1-1.—Work element estimate worksheet.

11

number, deployment location, year, project number, and project description.

A summary of work element quantities is prepared by transferring the totals on the worksheets to a summary sheet, which becomes the work element estimate. Work elements are arranged in the same sequence as they appear in the standard work element list so they will be in correct sequence for reporting or recording on work schedules. This summary sheet has the same information in the heading as the worksheet, except that it is shown as a work element estimate summary sheet. The body of the summary sheet shows the description and quantity of the work elements. If decisions have been made about how the work will be accomplished, indicate this by entry. For example, excavation is entered as machine excavation and backfill as machine backfill. Figure 1-2 is a typical work element estimate summary sheet.

Before proceeding, note that figures 1-1 through 1-6 illustrate the minimum amount of information which should appear on estimate sheets and should NOT be considered as standard worksheets. You may wish to record additional information or record work in a different manner. A main object to keep in mind is that the recording is to be detailed so that any one reviewing the estimate can understand what was taken off and how computations were made. If this procedure is followed, an independent check can be made without raising a question about how any quantity in the estimate was derived.



SHEET 1 OF 1
ESTIMATED BY Smith DATE 7-7--
CHECKED BY Jones DATE 8-10--

WORK ELEMENT ESTIMATE
SUMMARY SHEET

NMCB 74 LOCATION Diego Garcia YEAR 19-
PROJECT 08 DESCRIPTION Staging - Out Warehouse

WORK ELEMENT	QUANTITY
Footings and foundations	
Machine excavation	1860 CY
Machine backfill	1277 CY
Hand compaction	1277 CY
Spread excess earth - machine	583 CY
Form and strip	11,083 SFCS
Place reinf. steel	34.6 Tons
Place finish & cure concrete	582.8 CY

145.4

Figure 1-2.—Work element estimate summary sheet.

MATERIAL ESTIMATES

A material estimate is a listing and description of the various materials and the quantities required to construct a given project. Information for preparing material estimates is obtained from drawings and specifications. A material estimate is sometimes referred to as a Materials Takeoff (MTO).

Material estimates are used as a basis for construction material procurement, and also as a check to determine of sufficient materials are available to construct or to complete a project. For example, the operations officer might have some doubts about availability of materials to complete a certain project, so an estimate is prepared listing quantities of materials that will be required to complete the project. This estimate is compared with the stock of materials on hand to determine any shortage.

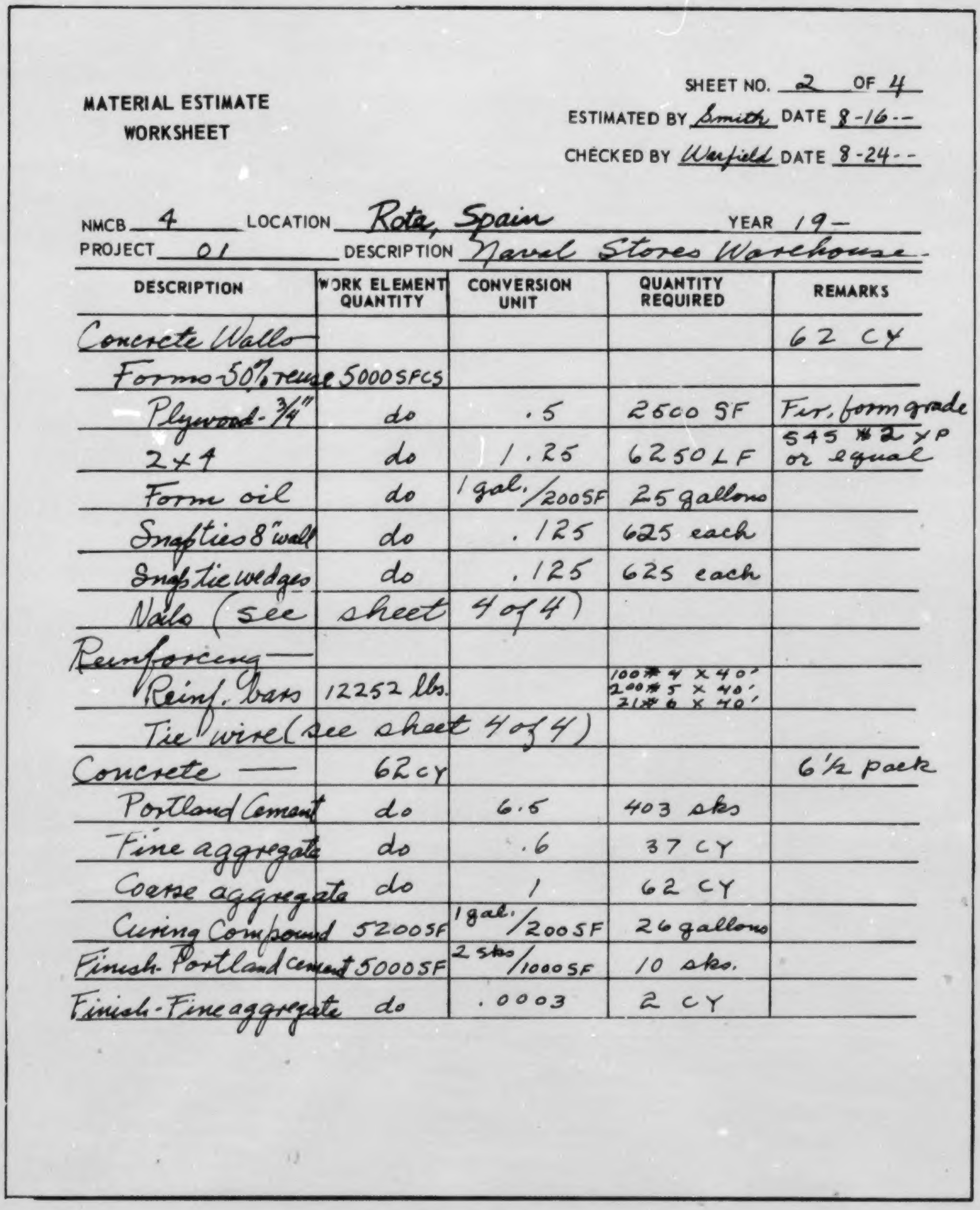
The following is a suggested procedure for preparation of a material estimate. First, obtain the work element quantity, which is usually done by referring to the work element estimate. Convert this into quantities of materials required to perform the work. (Conversion units which are available from the P & E Section of the NMCB Operations Department should be used whenever possible.) This conversion should be done on a worksheet which will record how each material quantity was obtained. A typical material estimate worksheet is shown in figure 1-3. It is important that worksheets be sufficiently detailed to be self-explanatory, so that anyone examining them can determine how quantities were computed without consulting the estimator. If desired, a sketch may be furnished to explain how the estimator planned the takeoff. After computing material quantities on the worksheets, enter them on recap sheets with like materials for a project grouped together and totaled. Allowances for waste and loss are added after the quantities are totaled. There are some items, such as reinforcing tie wire and nails, which are computed using a material quantity rather than a work element quantity. These computations should appear at the end of the worksheets, using total quantities obtained from the recap worksheet. Notes should be made on the worksheet to remind the estimator that these items are to be compared using total quantities from recap sheets. The recap worksheet becomes the material estimate. A sample of a typical recap worksheet is shown in figure 1-4.

During construction there is a certain amount of material wasted due to cutting, filling, and handling. For example, sand which is normally stored at the jobsite. The sand on the bottom of the pile cannot be picked up without getting some earth with it, which generally makes that sand unusable and therefore wasted. Allowance must be made in the materials estimate for this waste. There is also the possibility of loss due to pilferage and weather. Waste and loss factors as supplied by the P & E Section of the NMCB Operations Department are based on a large number of jobs performed under varied conditions and at many different locations. An estimator has specific information about the job and is in a position to determine if conditions warrant increasing the waste and loss factor normally used for any material item. This waste and loss factor can be varied when job conditions indicate that the normal factor is too low.

EQUIPMENT ESTIMATES

By definition, an equipment estimate is a listing of the type of equipment, the amount of time, and the number of pieces required to construct a given project. Information from work element estimates, drawings, and specifications, and information obtained from inspection of the site provide the basis for preparing the equipment estimate. Figure 1-5 illustrates the type of information shown in an equipment estimate. It is not practical to use a form with columns for work quantities, equipment quantities, and operation days when preparing the equipment estimate. However, forms with certain information in the heading, such as that shown in the heading of figure 1-5, will save estimator time.

Equipment estimates are used together with work schedules as a basis for determining the



MATERIAL ESTIMATE WORKSHEET

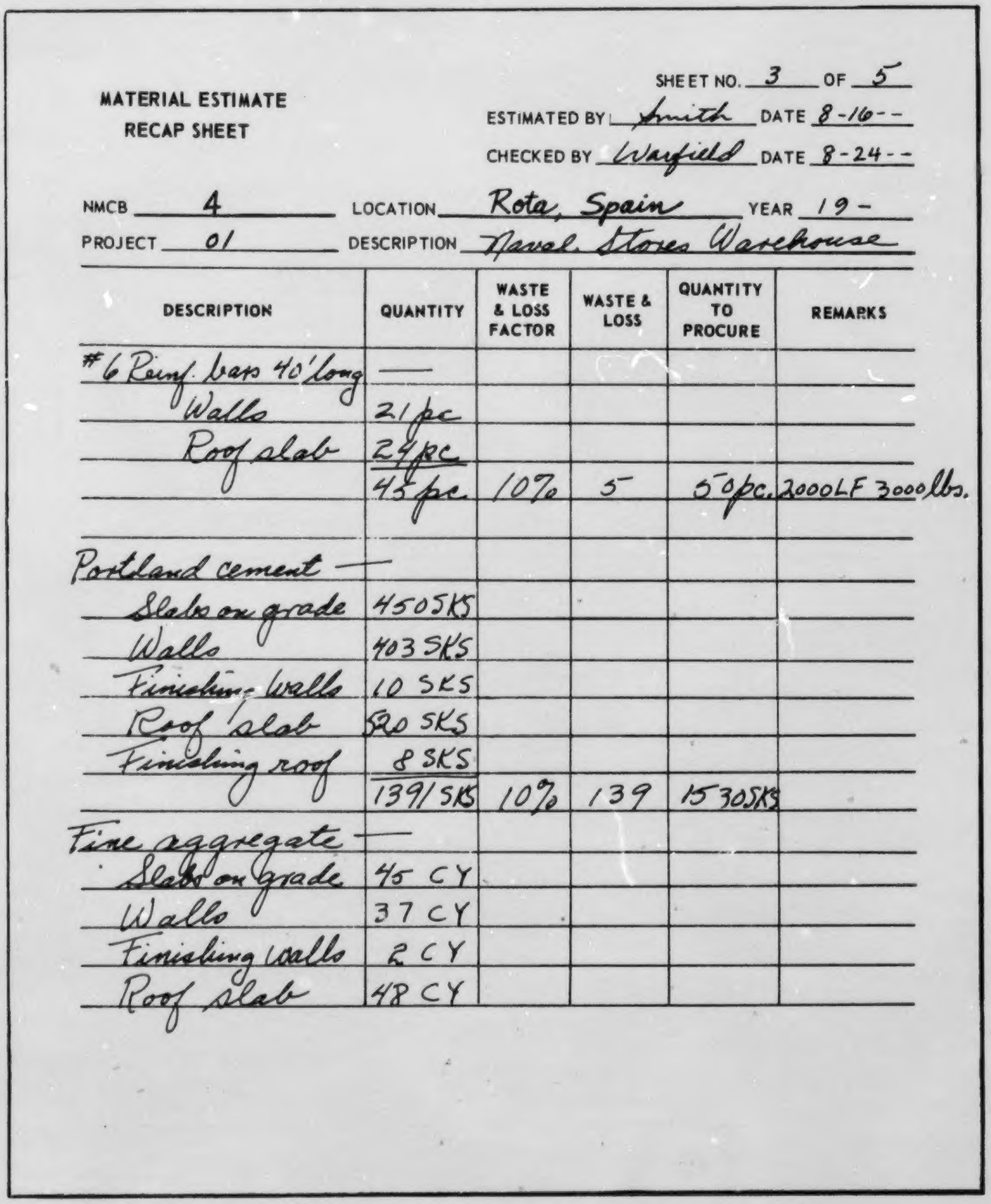
SHEET NO. 2 OF 4
ESTIMATED BY Smith DATE 8-16-–
CHECKED BY Warfield DATE 8-24-–

NMCB 4 LOCATION Rota, Spain YEAR 19–
PROJECT 01 DESCRIPTION Naval Stores Warehouse

DESCRIPTION	WORK ELEMENT QUANTITY	CONVERSION UNIT	QUANTITY REQUIRED	REMARKS
Concrete Walls –				62 CY
Forms-50% reuse	5000 SFCS			
Plywood-3/4"	do	.5	2500 SF	Fir, form grade
2×4	do	1.25	6250 LF	545 #2 YP or equal
Form oil	do	1 gal./200 SF	25 gallons	
Snapties 8" wall	do	.125	625 each	
Snaptie wedges	do	.125	625 each	
Nails (see	sheet	4 of 4)		
Reinforcing –				
Reinf. bars	12252 lbs.		100 #4 × 40' 200 #5 × 40' 21 #6 × 40'	
Tie wire (see	sheet	4 of 4)		
Concrete –	62 CY			6½ pack
Portland Cement	do	6.5	403 sks	
Fine aggregate	do	.6	37 CY	
Coarse aggregate	do	1	62 CY	
Curing Compound	5200 SF	1 gal./200 SF	26 gallons	
Finish-Portland cement	5000 SF	2 sks/1000 SF	10 sks.	
Finish-Fine aggregate	do	.0003	2 CY	

87.2

Figure 1-3.–Material estimate worksheet.



MATERIAL ESTIMATE RECAP SHEET

SHEET NO. 3 OF 5

ESTIMATED BY Smith DATE 8-16--

CHECKED BY Warfield DATE 8-24--

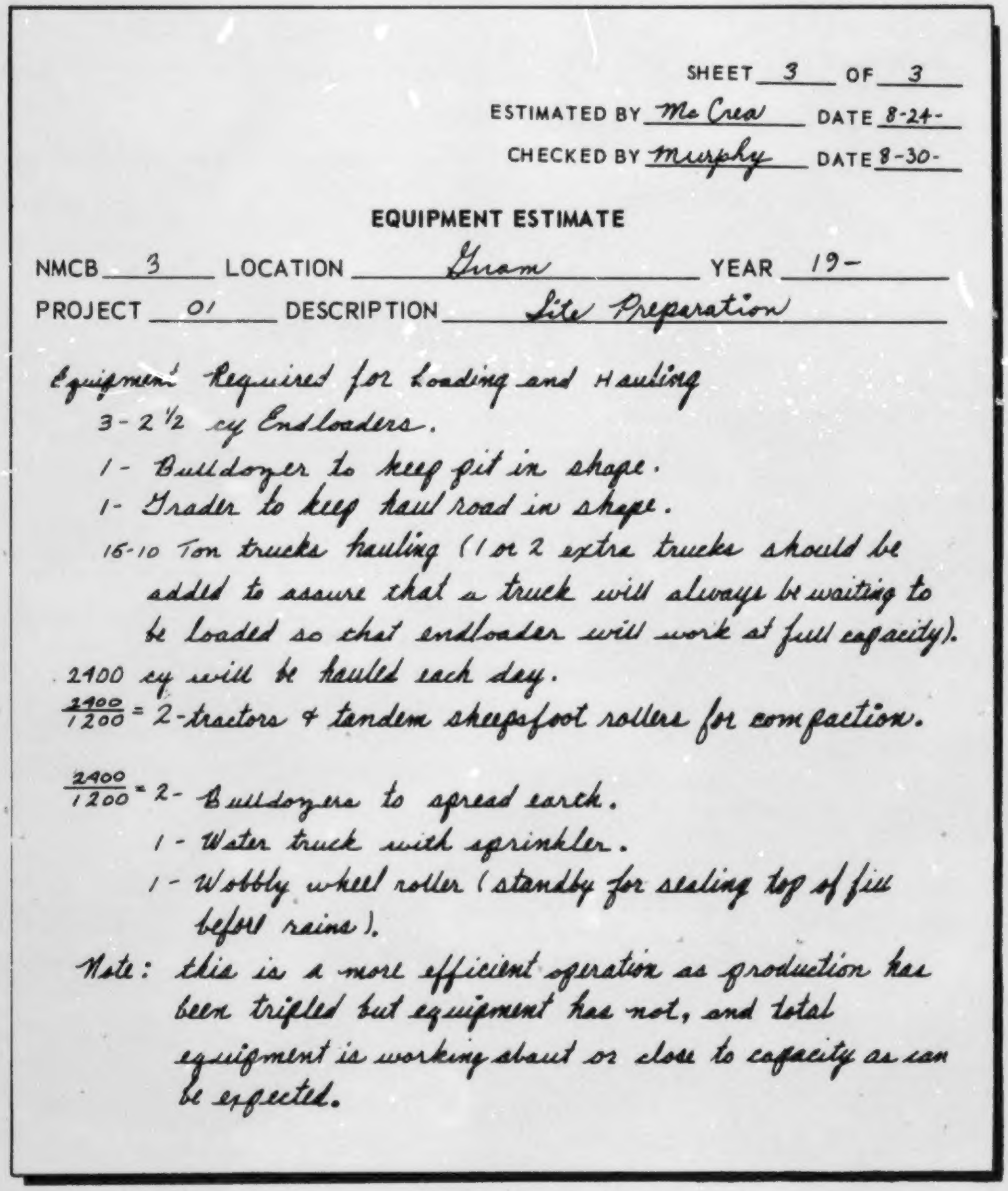
NMCB 4 LOCATION Rota, Spain YEAR 19-

PROJECT 01 DESCRIPTION Naval Stores Warehouse

DESCRIPTION	QUANTITY	WASTE & LOSS FACTOR	WASTE & LOSS	QUANTITY TO PROCURE	REMARKS
#6 Reinf. bars 40' long	—				
Walls	21 pc				
Roof slab	24 pc				
	45 pc.	10%	5	50 pc.	2000LF 3000 lbs.
Portland cement —					
Slabs on grade	450 SKS				
Walls	403 SKS				
Finishing walls	10 SKS				
Roof slab	520 SKS				
Finishing roof	8 SKS				
	1391 SKS	10%	139	1530 SKS	
Fine aggregate —					
Slabs on grade	45 CY				
Walls	37 CY				
Finishing walls	2 CY				
Roof slab	48 CY				

87.3

Figure 1-4.—Material estimate recap sheet.



SHEET 3 OF 3
ESTIMATED BY Mc Crea DATE 8-24-
CHECKED BY Murphy DATE 8-30-

EQUIPMENT ESTIMATE

NMCB 3 LOCATION Guam YEAR 19-
PROJECT 01 DESCRIPTION Site Preparation

Equipment Required for Loading and Hauling

3-2 1/2 cy Endloaders.

1- Bulldozer to keep pit in shape.

1- Grader to keep haul road in shape.

16-10 Ton trucks hauling (1 or 2 extra trucks should be added to assure that a truck will always be waiting to be loaded so that endloader will work at full capacity).

2400 cy will be hauled each day.

$\frac{2400}{1200}$ = 2-tractors & tandem sheepsfoot rollers for compaction.

$\frac{2400}{1200}$ = 2- Bulldozers to spread earth.

1- Water truck with sprinkler.

1- Wobbly wheel roller (standby for sealing top of fill before rains).

Note: this is a more efficient operation as production has been tripled but equipment has not, and total equipment is working about or close to capacity as can be expected.

145.5

Figure 1-5.—Equipment estimate.

construction equipment requirements of a project and the total construction equipment requirements of a SEABEE deployment. An estimate includes items such as pipe machines, welding machines, mortar mixers, and automotive equipment. It may also be used as a basis for estimating the amount of spare parts, the number of mechanics, the size of shops, and the tools and shop equipment needed to maintain construction equipment in operating condition during a deployment.

When preparing the equipment estimate, examine the work element estimate and list all work elements requiring equipment for their performance. For each work element on the list, select the type of equipment and method of performing the work. Estimate the production rate per day for each piece of equipment. The quantity of work is divided by the production rate per day to find out how many days of operation are required to perform the work. The various factors affecting production and sources of information used in determining equipment production rates are given later. Some elements of work require several items of equipment to be used as a group rather than individually; in these cases, the days of operation should be shown as days of group operation.

After determining the number of days of equipment operation required, consult the work schedule to find the time allotted for completion of the work element. It may be necessary to work several pieces or groups of equipment at the same time in order to complete the work within the scheduled time. Also, it may be advantageous to use several pieces or groups of equipment at the same time because it would result in more efficient operation. An equipment schedule should be prepared for the total deployment using the work schedule to determine when the work will be performed. The number of pieces of each equipment type required at any one time can be determined from this schedule. This schedule will indicate the peak workloads for each equipment type. A study of the peak loads may show that it is desirable to revise the work schedule to distribute the equipment workload more evenly and thereby reduce the amount of equipment required for a deployment.

Following a review of the equipment and work schedules, and making all possible adjustments to them, a list of the equipment requirements for the deployment can be prepared. In preparing this list anticipate downtime and add sufficient equipment so that when equipment is out of service awaiting repairs, a reserve piece is available for use. This is especially important for automotive equipment. The number of pieces of equipment required for a deployment is obtained by adding the required reserve equipment of each type to the peak figure indicated by the equipment schedule.

Factors Affecting Production

When you realize the importance of equipment in getting construction work done, you can see that special care is needed in preparing equipment estimates. You will often have to consider a number of factors before arriving at an estimate of how much work to expect from an individual piece of equipment. Some of the important factors affecting equipment production are: average speed at which the equipment will be operated, types of materials to be handled, experience of operators, age and condition of the equipment, time allotted for completion, climate, and safety.

Equipment Production Rates

Numerous sources of information about equipment production rates are available. These sources include manufacturers' tables and diagrams, Government manuals, and estimating books. Production rates are usually available in most SEABEE operations offices. However, it is not practical to draw up a production table which would consider the particular combination of factors affecting production on a given project. Production rates found in tables, therefore, must be adjusted to fit the conditions expected on the particular project being estimated. To make the adjustment intelligently, you should know on what basis the rate in the table was established. This information is usually contained in the foreword, in notes for the table, or in instructions for using the table.

MANPOWER ESTIMATES

A manpower estimate is a listing of the number of man-days required to complete the various work elements of a specific project. These estimates may show only the man-days for each work element and the total man-days, or they may be in sufficient detail to show the number of man-days of each rating; i.e., Equipment Operator, Builder, Steelworker, Utilitiesman, and so on for each work element. Manpower estimates are used in determining the number of personnel and ratings required on a deployment, and provide the basis for scheduling manpower in relation to construction progress. Two types of manpower estimates that you may prepare are preliminary and detailed estimates. A suggested procedure for preparing each type is given below.

Preliminary Estimates

Preliminary estimates are used to establish costs for succeeding years. They may be used as very rough checks of detailed estimates, but they can be expected to vary as much as 10 to 15 percent from the detailed estimate. Preliminary manpower estimates are prepared from limited information, such as general descriptions of projects or preliminary plans and specifications with little or no detailed information. They are usually prepared on the basis of area, length, or other suitable measurement.

In preparing preliminary manpower estimates on this basis, it is first necessary to compute the area or other measurement of the project from information at hand. Next, consider the conditions under which the project will be completed and select a suitable man-day per unit figure from tables. Then, multiply the quantity of measurement by the man-day figure selected to obtain the estimated man-days required for the project. For example, an EM club is to be built with reinforced concrete frame and roof, clay tile and plaster walls. The building is to be 60 feet wide x 80 feet long. The area is 60 feet x 80 feet = 4800 square feet. Assume that conditions at the project site will be favorable for construction. Table 1-1 shows that 0.4 man-days will be required for each square foot of area of this type of construction. So, 4800 x 0.4 man-days = 1920 man-days required for complete construction of the club.

Or, take the case of a 500-man camp consisting of butler buildings, with galley and reefers, complete with sanitary facilities, heat, electric power, water, and communications. Conditions at the site are such that a man-day unit figure halfway between average and adverse conditions is the correct one to use. Referring to table 1-1, the man-day per unit figures are 12 for adverse and 8 for average. Halfway between this figure is

$$\frac{8+12}{2} = 10 \text{ man-days per unit.}$$

Now, multiply 500 by 10 man-days to get 5000 man-days required to complete the camp.

Now take a close look at table 1-2, which may be used in the preparation of preliminary estimates for utility installation.

In using table 1-1 or table 1-2, you should select the man-days per unit figure after considering the various factors which might affect production at the site. These factors include: weather conditions during the construction period, skill and experience of the workers, time allotted for completion of the job, size of the crew, accessibility of the site, and types of material and equipment.

Remember that tables 1-1 and 1-2 are designed for the preparation of preliminary estimates, and may be used to obtain a quick estimate of manpower needs. They will not give nearly as accurate results as a detailed estimate which attempts to adjust for all factors affecting the number of man-days required to construct a project.

Detailed Estimates

Detailed manpower estimates are used to determine the manpower required for construction of a given project. They are also used to determine total direct labor requirements of a SEABEE deployment.

Table 1-1.—Housing and Special Services Building Construction

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
For preliminary estimates only:				
Masonry and concrete construction:				
BOQ	SF	0.95	0.60	0.40
Barracks	SF	0.85	0.55	0.35
Chapel	SF	1.5	1.0	0.6
Community center (60% under roof)	SF	0.45	0.30	0.20
CPO club	SF	1.5	0.8	0.5
Dry cleaning shop	SF	1.00	0.65	0.40
EM club	SF	1.2	0.8	0.4
Gymnasium	SF	1.2	0.8	0.5
Handball court (walls on 3 sides)	Each	800	540	350
Housing (family quarters)	SF	0.60	0.40	0.25
Library	SF	0.85	0.55	0.35
NCO club	SF	1.5	1.0	0.6
Officers mess and club	SF	1.5	1.1	0.7
Post exchange, ships store, and retail shops	SF	0.80	0.50	0.35
Roller skating rink (open sides)	SF	0.40	0.25	0.15
School	SF	1.2	0.8	0.5
Service station	SF	1.30	0.90	0.55
Theater	SF	2.00	1.35	0.89
Quonset or Butler bldg[1]	SF	0.15	0.10	0.06
Quonset camp complete[2]	Man	12	8	5

Note: Man-days per unit are for buildings completely equipped.

[1] Man-days shown do not include interior partition.

[2] Based on a complete camp with messing facilities, all utilities and lavatory facilities, administration buildings. Does not include shops.

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In preparing detailed manpower estimates, first obtain the work element quantity from the Work Element Estimate. Using the appropriate table, then select the man-days per unit figure and multiply by the quantity to obtain the total man-days required for the work element. If a work element estimate summary sheet (see Fig. 1-6) is prepared, you can use a copy of it as a manpower estimate worksheet. These worksheets record the manpower estimate when progress control is to be exercised to the extent detailed in the tables. If lesser control is desired,

Table 1-2.—Utility Installation

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
For preliminary estimates only:				
Avgas lines	LF	0.50	0.33	0.16
Emergency power plant (concrete earth covered)	SF	1.35	0.90	0.50
Fuel tanks (3000 to 10,000 (bbls)	Ea	500	350	225
Power lines	1000 LF	110	50	22
Pump house	SF	1.8	1.2	0.6
Sanitary lines (V.C.)	LF	0.60	0.30	0.10
Security lighting (overhead lines)	1000 LF	77	45	20
Septic tanks	Gal	0.15	0.10	0.05
Storm drainage	LF	.90	.50	.15
Street lighting	1000 LF	58	32	14
Telephone lines	1000 LF	35	16	7
Underground power systems	LF	0.75	0.30	0.07
Water lines (C.I.)	LF	0.38	0.24	0.11
Water tank (300,000 gal)	Ea	900	750	600
Water well complete	Ea	150	100	50

NOTE: Man-days per unit are for utilities complete including excavation and backfill.

87.105

a summary sheet should be prepared with the work elements detailed to the extent desired.

Table 1-3 illustrates the type of table which you might use in preparing detailed manpower estimates of excavation for footings and foundations. As an example in the use of this table, suppose that 20 housing units are to be constructed on an island in the Pacific. Also suppose that each house has 30 CY of excavation, 28 of which can be done by machine and 2 by hand. Furthermore, the island has a favorable climate, half of the crew will be experienced, and construction conditions are average. The computations are shown below:

20 x 28 = 560 CY by machine
20 x 2 = 40 CY by hand

Excavation 0.56 thousand CY x 25 man-days = 14 man-days

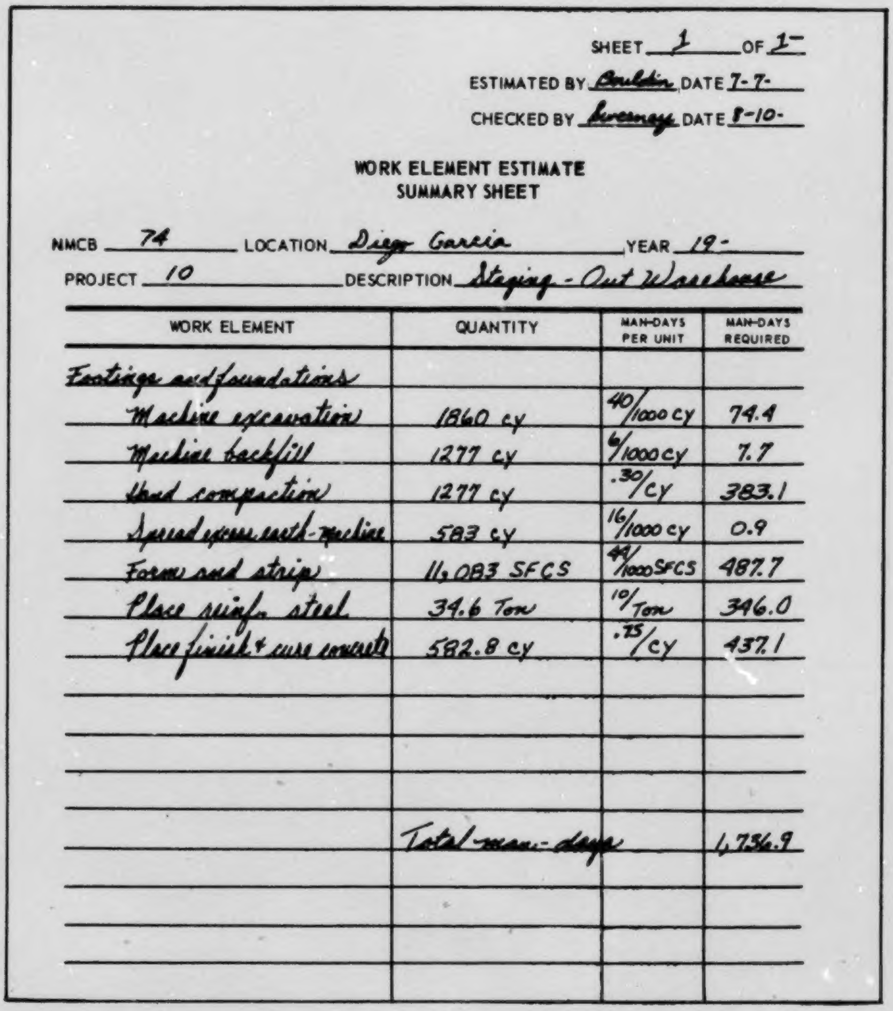
Load excess earth 0.56 thousand CY x 4.5 man-days = 2.52 man-days

Haul excess earth 0.56 thousand CY x 3.1 man-days = 1.74 man-days

Spread spoil pile 0.56 thousand CY x 1.4 man-days = 0.78 man-days

Spread excess earth 0.56 thousand CY x 3 man-days = 1.68 man-days

Backfill 0.56 thousand CY x 6 man-days = 3.36 man-days



SHEET 1 OF 1

ESTIMATED BY DATE 7-7-

CHECKED BY DATE 8-10-

WORK ELEMENT ESTIMATE
SUMMARY SHEET

NMCB 74 LOCATION Diego Garcia YEAR 19-

PROJECT 10 DESCRIPTION Staging - Out Warehouse

WORK ELEMENT	QUANTITY	MAN-DAYS PER UNIT	MAN-DAYS REQUIRED
Footings and foundations			
Machine excavation	1860 cy	40/1000 cy	74.4
Machine backfill	1277 cy	6/1000 cy	7.7
Hand compaction	1277 cy	.30/cy	383.1
Spread excess earth-machine	583 cy	16/1000 cy	0.9
Form and strip	11,083 SFCS	44/1000 SFCS	487.7
Place reinf. steel	34.6 Ton	10/Ton	346.0
Place finish + cure concrete	582.8 cy	.75/cy	437.1
	Total man-days		1,736.9

82.88

Figure 1-6.—Manpower estimate worksheet.

Compaction 0.56 thousand CY x 8 man-days = 4.48 man-days

Hand excavation 0.04 thousand CY x 0.7 man-days = 0.03 man-days

Total man-days for excavation is 28.59. Use 29 man-days.

Now closely observe table 1-4 which applies to the asphalt plant operation. As an example, a 125 tons per hour (TPH) batch plant is being considered for a construction job on an island in the tropics. The commanding officer wants an estimate of the man-days required to set up the plant.

The estimates of average SEABEE production, as listed in table 1-4, should fall at

Table 1-3.—Excavation for Footings and Foundations

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Machine excavation for footings and foundations:				
Excavation[1]	1000 CY	50	25	12
Load excess earth	1000 CY	9.0	4.5	2.0
Haul excess earth	1000 Yd. Mi.	5.2	3.1	1.4
Spread spoil pile	1000 CY	2.1	1.4	0.7
Spread excess earth	1000 CY	4.5	3.0	1.5
Backfill	1000 CY	9	6	3
Compaction	1000 CY	12	8	4
Hand excavation for footings and foundations:				
Excavation	CY	1.2	0.7	0.3
Load excess earth	CY	0.8	0.4	0.2
Spread excess earth	CY	0.18	0.12	0.06
Backfill	CY	0.35	0.20	0.10
Compaction	CY	0.55	0.35	0.15
For quick estimates for excavating footings and foundations:[2]				
Machine excavation, complete	1000 CY	72	38	18
Hand excavation, complete	CY	2.1	1.0	0.5

Typical crew: Machine work – 1 crew leader, 2 men on excavating equipment, 2 to 6 trucks with operators, 1 man on equipment spreading and backfilling, 1 man on compacting equipment.

Typical crew: Hand work – 1 crew leader, 2 to 10 men excavating, loading and/or spreading excess dirt, backfilling and tamping.

[1] Includes trimming and fine grading.

[2] Includes removal and disposal of excess dirt, backfilling, and compaction.

143.301

67% on the bottom of the graph shown in figure 1-7, which in turn will be a delay factor of 1.00 on the right. A delay factor of 0.66 represents peak production.

From table 1-4 you extract an estimate of 70 man-days to set up the plant. To adjust this figure to the conditions evaluated on your job, assume that the average of foreseen conditions is 87%. The corresponding delay factor read off the production efficiency graph in figure 1.7 is 0.80.

Find the adjusted man-day estimate by multiplying this delay factor by the man-days from table 1-4, such as shown in the following computation: 70 x 0.8 = 56 (the adjusted man-day estimate).

So 56 man-days would be a good figure to give to the commanding officer.

Among the many other tables which the EO is likely to use are tables 1-5 and 1-6. Table 1-5 is used in preparing detailed manpower estimates for rock crushing plant operation and table 1-6 is used for estimates that involve site preparation, clearing, and grubbing.

MATERIALS AND EQUIPMENT

To keep operations running smoothly you will have to see that the proper materials are available at the time they are needed. You must try to avoid a big excess in the supply of materials. At the same time, make sure that supplies are not exhausted before requesting new materials. If materials are not on hand when needed, personnel may have to stand idle, and delays in meeting production schedules could result.

SUPPLY PROCEDURES

To insure that an adequate supply of materials is on hand when needed, it is important that you be familiar with supply procedures. Details on supply procedures are not spelled out in this book. If not familiar with the proper procedures, you can get help from *Military Requirements for Petty Officer 3 & 2* and *Military Requirements for Petty Officer 1 & C.*

MATERIALS FLOW

The bill of materials should be checked during the planning stage to make certain that all materials are available or are on order. Even with this check, there is sometimes danger of running out of material. This may happen when the rate of progress on the job has been considerably greater than anticipated or when materials have been unusually slow in arriving at the jobsite. If either of these conditions occurs, notify the officer in charge of the project. This officer may appoint an expediter to see that materials get to the location where they are needed. Occasionally, you may serve as

Table 1-4.—Asphalt Plant Operation

Work Element Description	Unit	Man-days per unit
Set up and Dismantle Plant	Each	70.0
Operation of Asphalt Plant	1,000 Tons	10.0
Hauling Asphalt to Job	1,000 Ton Mi	6.0

SUGGESTED CREW SIZE:

Set up and dismantle plant

1 Crew leader
4 EO's
2 UT's
1 CE
1 CM

Asphalt plant operations

5 EO's

Hauling asphalt to job

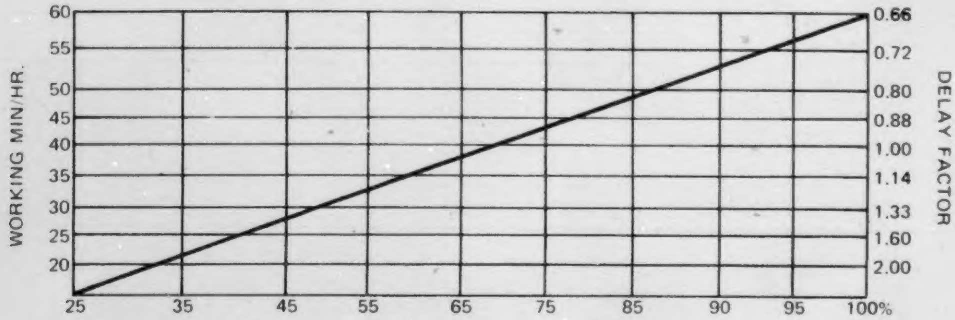
7 EO's

Maintenance (support)

2 UT's
1 CE
1 CM

NOTES:

1. Figures based on BLH 5,000 (125 TPH) batch plant.
2. Site preparation and concrete curing time not included in above set up and dismantle figure.



143.302

Figure 1-7.—Production efficiency graph.

Table 1-5.–Rock Crushing Plant Operation

Work Element Description	Unit	Man-days per unit
Set up and Dismantle	Each	40.0
Operating Crushing Plant	1,000 CY	24.0
Stockpiling Crushed Material	1,000 CY	3.0
Hauling Crushed Material to Job	1,000 YM	3.5

SUGGESTED CREW SIZE:

1 crew leader

3 men on plant

4 to 6 crewmembers for support as follows:

- 4 Equipment Operators
- 1 Steelworker and 1 Construction Electrician

NOTES:

1. The production figure is based upon 200 TPH plant operating at 50 percent of rated capacity crushing granite at 3,000 lb per loose cubic yard. For plants of other sizes use 50 percent of rated capacity and the size of your crew for your calculations.
2. Production figures may have to be adjusted in accordance with the type of material being processed, and with other varying circumstances. (EXAMPLE: Coral weighs approximately 2,000 lb per loose cubic yard.)

expediter; in this case, you will hand-carry a requisition through the supply chain to speed up delivery. Careful advance planning will contribute to an orderly flow of materials.

SITE DEPLOYMENT OF MATERIALS AND EQUIPMENT

Special attention should be given to the deployment of materials and equipment at the jobsite. Make it a point so see that the right materials are at the right place at the right time. Where equipment is needed to accomplish a job, make sure IN ADVANCE that it will be available and see that it is on hand at the required time.

At the jobsite you may have to arrange for the stowage of materials. In doing so, try to have the materials as close as possible to the place where they will be used.

It is a good practice to stow items of different lengths, sizes, or types into separate piles–screens, for example. Among other

Table 1-6.—Site Preparation, Clearing, and Grubbing

Work Element Description	Unit	Man-days per unit
CLEARING TREES AND BRUSH BY HAND		
Cutting Trees and Brush	1,000 SY	6.0
Piling and Burning	1,000 SY	1.2
Digging and Blasting Stumps	Each	0.2
Cutting Large Trees	Each	0.4
CLEARING AND GRUBBING WITH EQUIPMENT		
Clearing Trees and Brush	1,000 SY	0.7
Rooting Out Stumps	Each	0.2
Loading and Hauling	1,000 SY	1.4
Burning Trees and Brush	1,000 SY	0.5

SUGGESTED CREW SIZE:

HAND WORK:

1 crew leader

4 to 8 crewmembers with brushhooks

1 or 2 crewmembers with chain saws

MACHINE WORK:

1 crew leader

1 dozer operator

2 to 5 crewmembers with chain saws and axes (trimming large trees)

BURNING

2 to 5 crewmembers burning piled brush

NOTES:

1. Most stumps can be rooted out with a bulldozer, unless the ground is very hard.
2. Brush should not be burned until it has dried for several weeks. Old tires burned with the brush pile help to keep the fire going.
3. Figures above based on lightly wooded ground. For areas of dense woods or jungle double the figure. For areas with low brush with no trees use fifty percent of above figure.
4. Care should be taken when disposing of material not to violate burning and pollution restrictions. Future construction plans should be considered before burying. If hauling is necessary, use loading and hauling figure.

things, it will often be necessary to set up working areas for specific operations. If setting up a crushing and screening plant, for instance, you may need an area for cutting timbers for the cribbing of the plant. It will be an advantage, of course, if the working area is near the material stowage area, as well as near the job on which the materials are to be used.

By now, you should have acquired knowledge that will help you in the safe handling and stowing of various types of materials commonly used by EO's. Make sure that your crewmembers also know the safe methods of handling and stowing materials used in their work, and see that they wear proper safety apparel where required.

MAINTENANCE OF EQUIPMENT

If maximum production is to be achieved, each piece of equipment must be kept in peak operating condition. Except when shift work is required, each piece of equipment should be assigned to one individual operator. This operator has the responsibility for the daily and weekly preventive maintenance services of the equipment. It is essential that you make all operators understand and see that they meet this responsibility. If more than one operator is assigned to a piece of equipment (for example, when you are operating on shifts), you must be sure each operator of this equipment for a particular shift is responsible for daily and weekly preventive maintenance. You must also arrange for close liaison with the maintenance supervisor and support personnel who will handle repairs and major maintenance that are beyond the scope of the duties of the operator.

RECORDS AND REPORTS

As you advance in rating, you can expect your job to require an increased amount of paperwork. If you have to spend a great deal of time doing paperwork, you may want to assign an assistant to handle part of it; however, you will be responsible for seeing that the work is done right. Keeping all your records and reports up-to-date will enable you to keep a close check on each job, each crewmember, and each piece of equipment under your supervision. Records and reports provide a means of checking the accomplished job progress against the planned job progress. They also serve to summarize the experience gained on the present project, and become highly valuable aids in the planning and scheduling of future projects.

Your activity will have standard forms and blanks for keeping some of the required records and for making certain supply transactions, for example, job orders, work requests, and requisitions. In addition to these standard forms, various forms used for records and reports often are designed locally, and such forms may differ from one activity to another. At most activities you may find it advantageous to maintain logs, notebooks, charts, and so on, of your own design to meet your own specific needs.

ADMINISTERING A COMPANY ACCIDENT PREVENTION PROGRAM

Each command is required to establish a safety organization to develop, organize, and direct a comprehensive accident prevention program and to provide for the promulgation and enforcement of safety precautions and safe construction techniques. The safety program is usually under the direction of a SAFETY OFFICER designated by the commanding officer. The safety officer has the authority to take immediate steps to stop any operation where there is impending danger of injury to personnel or damage to equipment or material.

The safety officer lays out the safety program, after conducting job analyses and consultations with the supervisors in charge of the various phases of construction.

Under the direction of the Safety Officer, and with the assistance of the Safety Chief, each company is required to administer an accident prevention program. As an EO1 or EOC, you may be appointed to administer "A" Company's accident prevention program.

SUPERVISION AND SAFETY

Safety and production go hand in hand. Supervisors should consider the safety, health, and physical welfare of their personnel as one of their chief responsibilities.

In teaching a new job or operation, always emphasize the safety measures that apply. In planning your jobs, make sure you keep safety in mind; don't wait until after an accident to teach safety. Remember that a lost-time injury means a nonproducer. And a high accident rate certainly won't reflect favorably upon your ability to supervise. To show concern over the health and physical welfare of your crewmembers not only will pay off in production, but also will enable you to earn their respect.

Some pointers that will be useful in preventing accidents are outlined below:

A. Size up the job.
   1. Analyze the job and spot the hazards.
   2. Review the previous accident experience on the job.
   3. Get help, if needed, from your project officer.

B. Plan to control the hazards.
   1. Weigh means for controlling the hazards.
   2. Select the right methods and the right personnel for the job.
   3. Decide on the proper tools and equipment.
   4. Check for protective equipment needs.

C. Work your plan.
   1. Make specific work assignments and give instructions.
   2. Check to see that everyone understands what is expected of them and that they do it.
   3. Remove hazards or protect the crew against them.
   4. Insist on safe practices.

D. Check results.
   1. Was the plan followed?
   2. How could the plan have been improved?
   3. What hazardous conditions or work practices, if any, need further attention?

SAFEGUARDS AND SAFETY EDUCATION

Many supervisors feel that it is only necessary to provide safeguards and safety will then take care of itself. Provision of safeguards is a move in the right direction, but it alone will not get good results. To maintain a good safety record, you, as the supervisor, need to employ a combination of safety devices and safety training. If all your crewmembers have had sound safety training, they will be able to guard against even those hazards where safety devices are impracticable. You must, however, train them in the use of safeguards, explaining why, as well as how, they should be used. How many times have you seen a crewmember shut off the power on a machine and then walk away from it before it has stopped turning? Such a person uses a safeguard, but does not know why. By providing the necessary training, you, as an alert supervisor, must make sure that such careless uses of safeguards do NOT happen again.

Standup safety meetings should be held in the field once every week. The meetings should be held at or near the work area. Instead of a routine safety lecture, it is much better to hold a group discussion on specific accidents that are to be guarded against or that may have happened in the unit. Crewmembers should be encouraged to express their ideas. A group conclusion about how specific accidents can be prevented should be reached.

Another type of safety meeting is one in which you present a safety problem that has developed because of new work or new equipment. Again, crewmembers should be invited to express their ideas.

A third type of safety meeting is one in which actual demonstrations and practice by the group are carried out. You might demonstrate how to lift, and then have the crew practice lifting. Also, to make the reason for lifting in this manner more realistic, a little lesson on the classes of tools and a little problem in ratio and proportion should prove interesting.

If you are demonstrating how to use a forklift—bring in a forklift and use it—do not just talk about how to use it. Then, again, let the crew practice.

Making these meetings interesting is of the utmost importance. You should not complain or scold, and the meetings should be limited in time. The subject matter should be thought out carefully in advance and it should be timely. Considerable ingenuity is required to keep these meetings from degenerating into dull routine affairs. Some supervisors have the crewmembers themselves rotate as leaders of the safety meetings—an excellent device to maintain interest. Hundreds of good motion pictures and other visual aids are available on safety subjects. Use them!

As company safety administrator, you are required to submit safety meeting reports periodically to the Safety Chief. You must keep a record of all meetings conducted within the company. Information required for this report will include the topics discussed, the number of personnel attending, and the length of the meeting.

SAFETY INSPECTIONS

In order to do your part in the administration of the safety program, you must have a thorough knowledge of the safety precautions which apply to the various types and phases of construction involving personnel and equipment. Furthermore, you must carry out the recommendations of the safety officer, which usually include the following:

1. Promulgate and enforce all safety regulations.
2. Instruct and drill your crewmembers in safe practices.
3. Caution your crew with regard to occupational hazards.
4. Inspect work areas regularly.
5. Assign crewmembers to jobs that are not beyond their technical and physical capabilities.
6. Report accidents, analyze them, and recommend appropriate action to prevent recurrence.

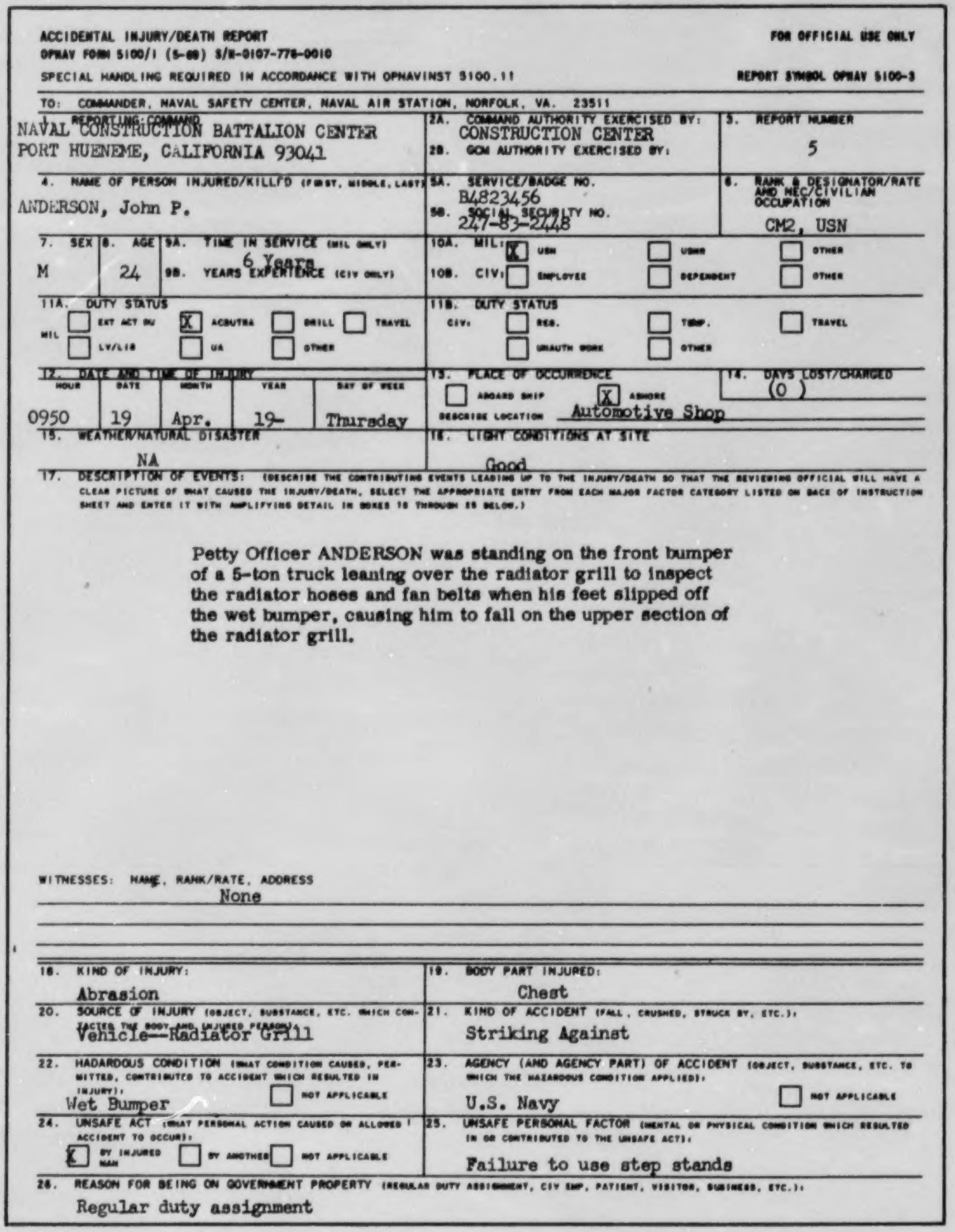
ACCIDENT REPORTING

When an accident occurs in your shop, office, or within your crew, you must fill out an OPNAV Form 5100/1 Accidental Injury/Death Report (figures 1-8 through 1-11). This form provides a method of recording the essential facts concerning an accident, from which data for use in accident prevention can be compiled. Item 27—"Corrective action taken/recommended"—is the most important part of this report. Your response to this item provides a clue to your attitude toward safety. Too many supervisors respond with, "The crewmember was warned to be more careful." Such a response is useless since it does not tie in with the rest of the report. If an unsafe working condition is the cause of the accident, you cannot correct it by warning the crewmember to be more careful. Study the report; analyze it; then take corrective action. When properly used, this report is one of your best accident prevention tools. In many cases, the difference between a minor accident and a major one is a matter of luck. Do not ignore accidents that result in small cuts and bruises; investigate the reason for them and correct the causes. If you do this, you will have a safe and efficient shop or office.

ACCIDENT INVESTIGATION

To fill out OPNAV Form 5100/1 properly, as shown in figures 1-8 and 1-9, you must conduct an accident investigation to get answers to questions, such as those in the six categories below.

1. Unsafe conditions. Was the equipment improperly guarded, unguarded, or inadequately guarded? Was the equipment or material rough, slippery, sharp-edged, decayed, worn, or cracked? Was there a hazardous arrangement, such as congested work space, lack of proper lifting equipment or unsafe planning? Was the proper safety apparel being worn? Were the proper respirator, goggle, gloves, etc., provided?
2. Type of accident. Did an object strike the person? Did the person fall at the same level or a different level or get caught between objects, or slip (not fall)?



ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69) S/N-0107-776-0010
SPECIAL HANDLING REQUIRED IN ACCORDANCE WITH OPNAVINST 5100.11

FOR OFFICIAL USE ONLY
REPORT SYMBOL OPNAV 5100-3

TO: COMMANDER, NAVAL SAFETY CENTER, NAVAL AIR STATION, NORFOLK, VA. 23511

1. REPORTING COMMAND
NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA 93041

2A. COMMAND AUTHORITY EXERCISED BY: CONSTRUCTION CENTER
2B. GCM AUTHORITY EXERCISED BY:

3. REPORT NUMBER 5

4. NAME OF PERSON INJURED/KILLED (FIRST, MIDDLE, LAST) ANDERSON, John P.

5A. SERVICE/BADGE NO. B4823456
5B. SOCIAL SECURITY NO. 247-83-2448

6. RANK & DESIGNATOR/RATE AND NEC/CIVILIAN OCCUPATION CM2, USN

7. SEX M
8. AGE 24
9A. TIME IN SERVICE (MIL ONLY) 6 Years
9B. YEARS EXPERIENCE (CIV ONLY)

10A. MIL: ☒ USN ☐ USNR ☐ OTHER
10B. CIV: ☐ EMPLOYEE ☐ DEPENDENT ☐ OTHER

11A. DUTY STATUS
MIL ☐ EXT ACT DU ☒ ACDUTRA ☐ DRILL ☐ TRAVEL
☐ LV/LIB ☐ UA ☐ OTHER

11B. DUTY STATUS
CIV: ☐ REG. ☐ TEMP. ☐ TRAVEL
☐ UNAUTH WORK ☐ OTHER

12. DATE AND TIME OF INJURY

HOUR	DATE	MONTH	YEAR	DAY OF WEEK
0950	19	Apr.	19-	Thursday

13. PLACE OF OCCURRENCE ☐ ABOARD SHIP ☒ ASHORE
DESCRIBE LOCATION Automotive Shop

14. DAYS LOST/CHARGED (0)

15. WEATHER/NATURAL DISASTER NA

16. LIGHT CONDITIONS AT SITE Good

17. DESCRIPTION OF EVENTS: (DESCRIBE THE CONTRIBUTING EVENTS LEADING UP TO THE INJURY/DEATH SO THAT THE REVIEWING OFFICIAL WILL HAVE A CLEAR PICTURE OF WHAT CAUSED THE INJURY/DEATH, SELECT THE APPROPRIATE ENTRY FROM EACH MAJOR FACTOR CATEGORY LISTED ON BACK OF INSTRUCTION SHEET AND ENTER IT WITH AMPLIFYING DETAIL IN BOXES 18 THROUGH 25 BELOW.)

Petty Officer ANDERSON was standing on the front bumper of a 5-ton truck leaning over the radiator grill to inspect the radiator hoses and fan belts when his feet slipped off the wet bumper, causing him to fall on the upper section of the radiator grill.

WITNESSES: NAME, RANK/RATE, ADDRESS
None

18. KIND OF INJURY: Abrasion

19. BODY PART INJURED: Chest

20. SOURCE OF INJURY (OBJECT, SUBSTANCE, ETC. WHICH CONTACTED THE BODY AND INJURED PERSON): Vehicle—Radiator Grill

21. KIND OF ACCIDENT (FALL, CRUSHED, STRUCK BY, ETC.): Striking Against

22. HADARDOUS CONDITION (WHAT CONDITION CAUSED, PERMITTED, CONTRIBUTED TO ACCIDENT WHICH RESULTED IN INJURY): Wet Bumper ☐ NOT APPLICABLE

23. AGENCY (AND AGENCY PART) OF ACCIDENT (OBJECT, SUBSTANCE, ETC. TO WHICH THE HAZARDOUS CONDITION APPLIED): U.S. Navy ☐ NOT APPLICABLE

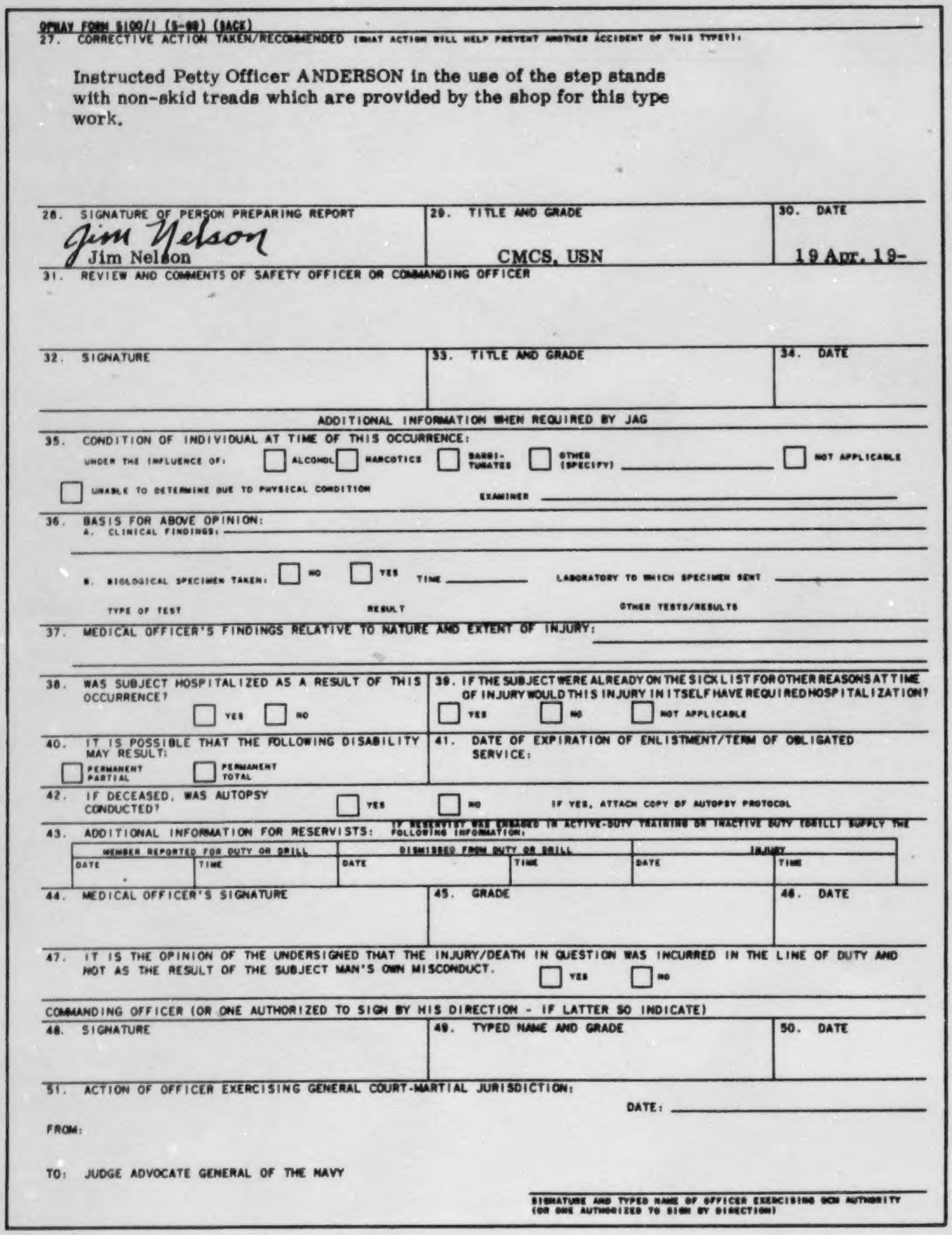
24. UNSAFE ACT (WHAT PERSONAL ACTION CAUSED OR ALLOWED ACCIDENT TO OCCUR): ☒ BY INJURED MAN ☐ BY ANOTHER ☐ NOT APPLICABLE

25. UNSAFE PERSONAL FACTOR (MENTAL OR PHYSICAL CONDITION WHICH RESULTED IN OR CONTRIBUTED TO THE UNSAFE ACT): Failure to use step stands

26. REASON FOR BEING ON GOVERNMENT PROPERTY (REGULAR DUTY ASSIGNMENT, CIV EMP, PATIENT, VISITOR, BUSINESS, ETC.): Regular duty assignment

2.462

Figure 1-8.—Accidental Injury/Death Report, OPNAV Form 5100/1 (Front).



OPNAV FORM 5100/1 (5-80) (BACK)

27. CORRECTIVE ACTION TAKEN/RECOMMENDED (WHAT ACTION WILL HELP PREVENT ANOTHER ACCIDENT OF THIS TYPE?):

Instructed Petty Officer ANDERSON in the use of the step stands with non-skid treads which are provided by the shop for this type work.

28. SIGNATURE OF PERSON PREPARING REPORT Jim Nelson Jim Nelson	29. TITLE AND GRADE CMCS, USN	30. DATE 19 Apr. 19-

31. REVIEW AND COMMENTS OF SAFETY OFFICER OR COMMANDING OFFICER

32. SIGNATURE	33. TITLE AND GRADE	34. DATE

ADDITIONAL INFORMATION WHEN REQUIRED BY JAG

35. CONDITION OF INDIVIDUAL AT TIME OF THIS OCCURRENCE:
UNDER THE INFLUENCE OF: ☐ ALCOHOL ☐ NARCOTICS ☐ BARBITURATES ☐ OTHER (SPECIFY) ______ ☐ NOT APPLICABLE
☐ UNABLE TO DETERMINE DUE TO PHYSICAL CONDITION EXAMINER ______

36. BASIS FOR ABOVE OPINION:
A. CLINICAL FINDINGS: ______
B. BIOLOGICAL SPECIMEN TAKEN: ☐ NO ☐ YES TIME ______ LABORATORY TO WHICH SPECIMEN SENT ______
TYPE OF TEST RESULT OTHER TESTS/RESULTS

37. MEDICAL OFFICER'S FINDINGS RELATIVE TO NATURE AND EXTENT OF INJURY: ______

38. WAS SUBJECT HOSPITALIZED AS A RESULT OF THIS OCCURRENCE? ☐ YES ☐ NO	39. IF THE SUBJECT WERE ALREADY ON THE SICK LIST FOR OTHER REASONS AT TIME OF INJURY WOULD THIS INJURY IN ITSELF HAVE REQUIRED HOSPITALIZATION? ☐ YES ☐ NO ☐ NOT APPLICABLE
40. IT IS POSSIBLE THAT THE FOLLOWING DISABILITY MAY RESULT: ☐ PERMANENT PARTIAL ☐ PERMANENT TOTAL	41. DATE OF EXPIRATION OF ENLISTMENT/TERM OF OBLIGATED SERVICE:

42. IF DECEASED, WAS AUTOPSY CONDUCTED? ☐ YES ☐ NO IF YES, ATTACH COPY OF AUTOPSY PROTOCOL

43. ADDITIONAL INFORMATION FOR RESERVISTS: IF RESERVIST WAS ENGAGED IN ACTIVE-DUTY TRAINING OR INACTIVE DUTY (DRILL) SUPPLY THE FOLLOWING INFORMATION:

MEMBER REPORTED FOR DUTY OR DRILL		DISMISSED FROM DUTY OR DRILL		INJURY	
DATE	TIME	DATE	TIME	DATE	TIME

44. MEDICAL OFFICER'S SIGNATURE	45. GRADE	46. DATE

47. IT IS THE OPINION OF THE UNDERSIGNED THAT THE INJURY/DEATH IN QUESTION WAS INCURRED IN THE LINE OF DUTY AND NOT AS THE RESULT OF THE SUBJECT MAN'S OWN MISCONDUCT. ☐ YES ☐ NO

COMMANDING OFFICER (OR ONE AUTHORIZED TO SIGN BY HIS DIRECTION - IF LATTER SO INDICATE)

48. SIGNATURE	49. TYPED NAME AND GRADE	50. DATE

51. ACTION OF OFFICER EXERCISING GENERAL COURT-MARTIAL JURISDICTION:
DATE: ______

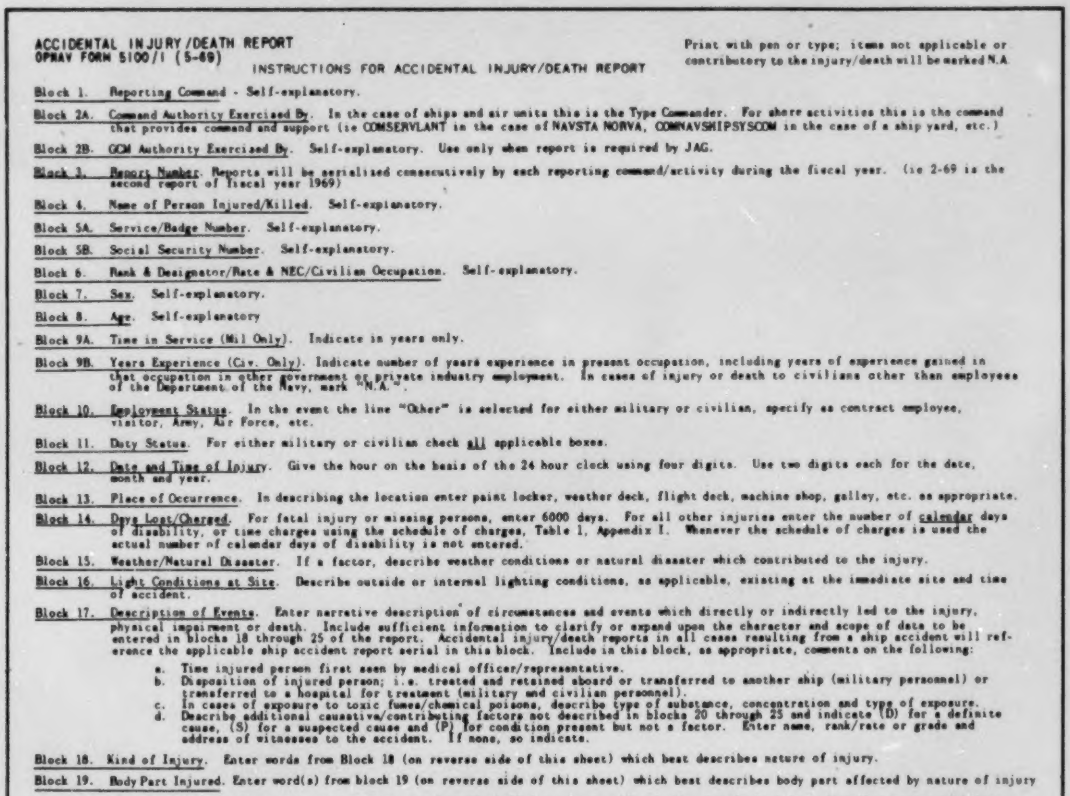
FROM:

TO: JUDGE ADVOCATE GENERAL OF THE NAVY

SIGNATURE AND TYPED NAME OF OFFICER EXERCISING GCM AUTHORITY
(OR ONE AUTHORIZED TO SIGN BY DIRECTION)

2.463

Figure 1-9.—Accidental Injury/Death Report, OPNAV Form 5100/1 (Back).



ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69)

Print with pen or type; items not applicable or contributory to the injury/death will be marked N.A

INSTRUCTIONS FOR ACCIDENTAL INJURY/DEATH REPORT

Block 1. Reporting Command - Self-explanatory.

Block 2A. Command Authority Exercised By. In the case of ships and air units this is the Type Commander. For shore activities this is the command that provides command and support (ie COMSERVLANT in the case of NAVSTA NORVA, COMNAVSHIPSYSCOM in the case of a ship yard, etc.)

Block 2B. GCM Authority Exercised By. Self-explanatory. Use only when report is required by JAG.

Block 3. Report Number. Reports will be serialized consecutively by each reporting command/activity during the fiscal year. (ie 2-69 is the second report of fiscal year 1969)

Block 4. Name of Person Injured/Killed. Self-explanatory.

Block 5A. Service/Badge Number. Self-explanatory.

Block 5B. Social Security Number. Self-explanatory.

Block 6. Rank & Designator/Rate & NEC/Civilian Occupation. Self-explanatory.

Block 7. Sex. Self-explanatory.

Block 8. Age. Self-explanatory

Block 9A. Time in Service (Mil Only). Indicate in years only.

Block 9B. Years Experience (Civ. Only). Indicate number of years experience in present occupation, including years of experience gained in that occupation in other government or private industry employment. In cases of injury or death to civilians other than employees of the Department of the Navy, mark "N.A.".

Block 10. Employment Status. In the event the line "Other" is selected for either military or civilian, specify as contract employee, visitor, Army, Air Force, etc.

Block 11. Duty Status. For either military or civilian check all applicable boxes.

Block 12. Date and Time of Injury. Give the hour on the basis of the 24 hour clock using four digits. Use two digits each for the date, month and year.

Block 13. Place of Occurrence. In describing the location enter paint locker, weather deck, flight deck, machine shop, galley, etc. as appropriate.

Block 14. Days Lost/Charged. For fatal injury or missing persons, enter 6000 days. For all other injuries enter the number of calendar days of disability, or time charges using the schedule of charges, Table 1, Appendix I. Whenever the schedule of charges is used the actual number of calendar days of disability is not entered.

Block 15. Weather/Natural Disaster. If a factor, describe weather conditions or natural disaster which contributed to the injury.

Block 16. Light Conditions at Site. Describe outside or internal lighting conditions, as applicable, existing at the immediate site and time of accident.

Block 17. Description of Events. Enter narrative description of circumstances and events which directly or indirectly led to the injury, physical impairment or death. Include sufficient information to clarify or expand upon the character and scope of data to be entered in blocks 18 through 25 of the report. Accidental injury/death reports in all cases resulting from a ship accident will reference the applicable ship accident report serial in this block. Include in this block, as appropriate, comments on the following:

a. Time injured person first seen by medical officer/representative.
b. Disposition of injured person; i.e. treated and retained aboard or transferred to another ship (military personnel) or transferred to a hospital for treatment (military and civilian personnel).
c. In cases of exposure to toxic fumes/chemical poisons, describe type of substance, concentration and type of exposure.
d. Describe additional causative/contributing factors not described in blocks 20 through 25 and indicate (D) for a definite cause, (S) for a suspected cause and (P) for condition present but not a factor. Enter name, rank/rate or grade and address of witnesses to the accident. If none, so indicate.

Block 18. Kind of Injury. Enter words from Block 18 (on reverse side of this sheet) which best describes nature of injury.

Block 19. Body Part Injured. Enter word(s) from block 19 (on reverse side of this sheet) which best describes body part affected by nature of injury

Block 20. Source of Injury. Enter object or environment from block 20 (on reverse side of this sheet) which best describes source of injury. (NOTE: A direct logical relationship between "Source of Injury" and "Kind of Injury" must be established).

Block 21. Kind of Accident. Enter action, motion or type of contact from block 21 (on reverse side of this sheet) which best describes means by which injured person came in contact with previously selected "Source of Injury". (NOTE: A direct logical relationship between the "Source of Injury" and "Kind of Accident" must be established.)

Block 22. Hazardous Condition. Enter the condition from Block 22 (on reverse side of this sheet) which best describes the hazardous condition which permitted or occasioned occurrence of previously selected "kind of Accident". (NOTE: A direct logical relationship between "Kind of Accident", "Hazardous Condition" and "Agency of Accident", which is to follow, must be established).

Block 23. Agency (and Agency Part) of Accident. Enter the object or environment from Block 20 (on reverse side of this sheet) which best describes the agency to which the hazardous condition applies. In addition, describe the part of the agency which is unsafe. For instance, if the agency is a table saw from which the blade guard has been removed, enter the words "cross cut saw - blade." In some agencies such as a length of pipe, rope, lumber, etc., no agency part is required to be named. The rule for agency part is - if corrective or preventive action for the part involved is different from the action on any other part of the agency, name the agency part involved. (NOTE: A direct logical relationship between "Hazardous Condition" and "Agency of Accident" must be established). If there is no hazardous condition there can be no agency or agency part of accident, and all three items shall be described as "Not Applicable".

Block 24. Unsafe Act. Enter the act or ommission from Block 24 (on reverse side of this sheet) which best describes unsafe act which permitted or caused occurrence of previously named kind of accident. (NOTE: A direct logical relationship between "Unsafe Act" and "Kind of Accident" must be established).

Block 25. Unsafe Personal Factor. Enter the reason from Block 25 (on reverse side of this sheet) which best describes the unsafe personal factor which led to the "Unsafe Act" or contributed to the injury. (NOTE: If there was an unsafe act committed, an unsafe personal factor should always be selected. If no unsafe act was committed there may still, however, be an unsafe personal factor which contributed to the accident).

Block 26. Reason for Being on Government Property. Self-explanatory.

Block 27. Corrective Action Taken/Recommended. List specific remedial actions which have been or should be taken to prevent recurrence of similar injury. If an entry of "unknown" or "none" seems appropriate, an explanation shall be given as to why corrective action can not be recommended. Specify whether actions have been taken or are only recommended. If the latter, what action is expected?

Blocks 28 through 30. First Signature Line. Report is to be signed and dated by the individual who prepared the report to this point.

Block 31. Review and Comments of Safety Officer or Commanding Officer. Additional recommendations may be made if appropriate.

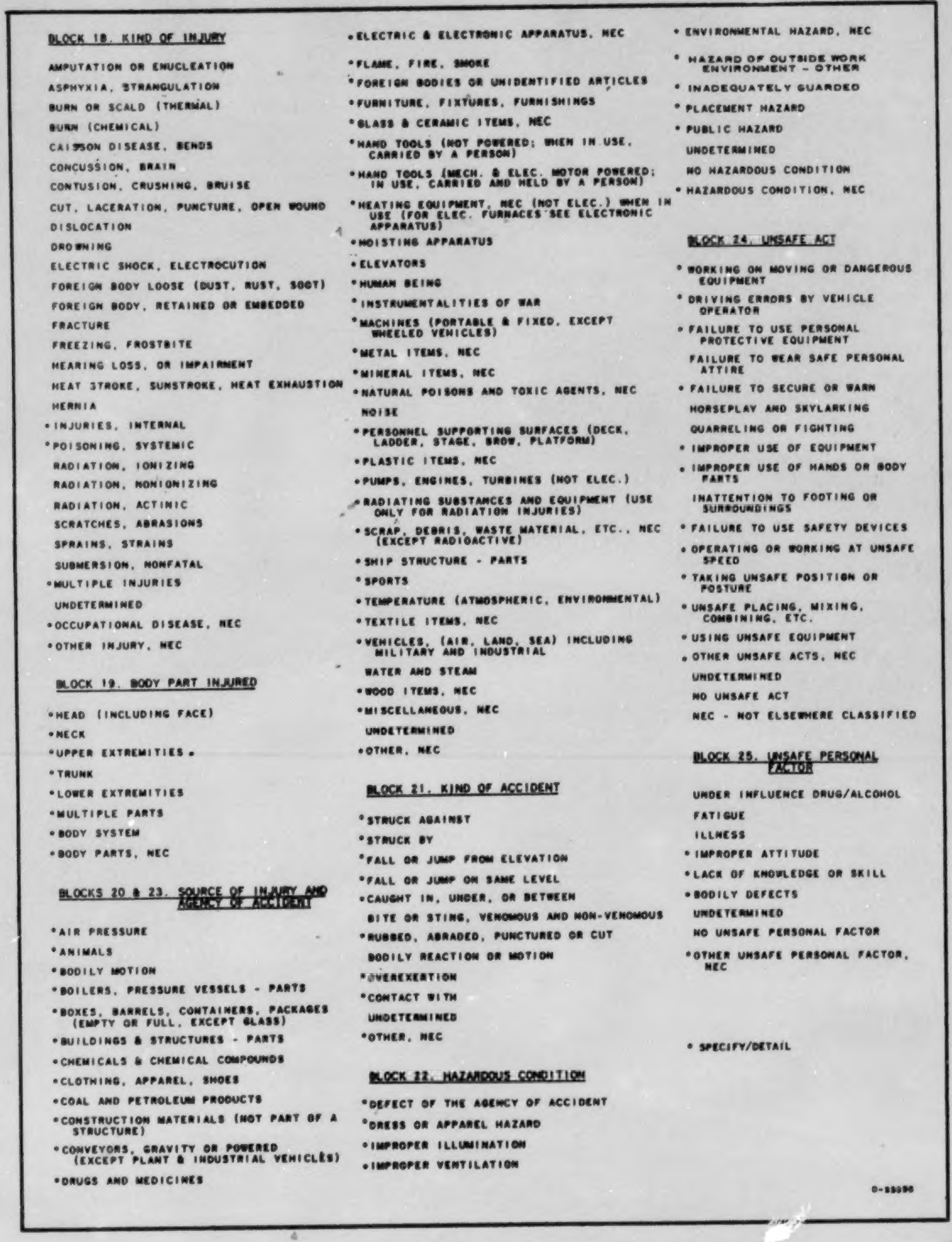
Blocks 32 through 34. Second Signature Line. Self-explanatory.

The remainder of the report form will only be filled out in those instances where the injury/death to the military member is reportable to JAG.

a. Blocks 1-34. Prepared in accordance with above instructions.
b. Blocks 35-50. Self-explanatory.
c. Blocks 35 through 40, 42, and 44 through 46 shall be completed and signed by the medical officer on the basis of his observation or examination of the injured or deceased member and information then available to him.
d. Blocks 41, 43 and 47 through 50 shall be completed and signed by the commanding officer on the basis of his investigation (or by an officer authorized and directed by the commanding officer to investigate the incident and sign the report by direction).

29.52

Figure 1-10.—Instructions for Accidental Injury/Death Report (Front).



BLOCK 18. KIND OF INJURY

AMPUTATION OR ENUCLEATION
ASPHYXIA, STRANGULATION
BURN OR SCALD (THERMAL)
BURN (CHEMICAL)
CAISSON DISEASE, BENDS
CONCUSSION, BRAIN
CONTUSION, CRUSHING, BRUISE
CUT, LACERATION, PUNCTURE, OPEN WOUND
DISLOCATION
DROWNING
ELECTRIC SHOCK, ELECTROCUTION
FOREIGN BODY LOOSE (DUST, RUST, SOOT)
FOREIGN BODY, RETAINED OR EMBEDDED
FRACTURE
FREEZING, FROSTBITE
HEARING LOSS, OR IMPAIRMENT
HEAT STROKE, SUNSTROKE, HEAT EXHAUSTION
HERNIA
•INJURIES, INTERNAL
•POISONING, SYSTEMIC
RADIATION, IONIZING
RADIATION, NONIONIZING
RADIATION, ACTINIC
SCRATCHES, ABRASIONS
SPRAINS, STRAINS
SUBMERSION, NONFATAL
•MULTIPLE INJURIES
UNDETERMINED
•OCCUPATIONAL DISEASE, NEC
•OTHER INJURY, NEC

BLOCK 19. BODY PART INJURED

•HEAD (INCLUDING FACE)
•NECK
•UPPER EXTREMITIES
•TRUNK
•LOWER EXTREMITIES
•MULTIPLE PARTS
•BODY SYSTEM
•BODY PARTS, NEC

BLOCKS 20 & 23. SOURCE OF INJURY AND AGENCY OF ACCIDENT

•AIR PRESSURE
•ANIMALS
•BODILY MOTION
•BOILERS, PRESSURE VESSELS - PARTS
•BOXES, BARRELS, CONTAINERS, PACKAGES (EMPTY OR FULL, EXCEPT GLASS)
•BUILDINGS & STRUCTURES - PARTS
•CHEMICALS & CHEMICAL COMPOUNDS
•CLOTHING, APPAREL, SHOES
•COAL AND PETROLEUM PRODUCTS
•CONSTRUCTION MATERIALS (NOT PART OF A STRUCTURE)
•CONVEYORS, GRAVITY OR POWERED (EXCEPT PLANT & INDUSTRIAL VEHICLES)
•DRUGS AND MEDICINES
•ELECTRIC & ELECTRONIC APPARATUS, NEC
•FLAME, FIRE, SMOKE
•FOREIGN BODIES OR UNIDENTIFIED ARTICLES
•FURNITURE, FIXTURES, FURNISHINGS
•GLASS & CERAMIC ITEMS, NEC
•HAND TOOLS (NOT POWERED; WHEN IN USE, CARRIED BY A PERSON)
•HAND TOOLS (MECH. & ELEC. MOTOR POWERED; IN USE, CARRIED AND HELD BY A PERSON)
•HEATING EQUIPMENT, NEC (NOT ELEC.) WHEN IN USE (FOR ELEC. FURNACES SEE ELECTRONIC APPARATUS)
•HOISTING APPARATUS
•ELEVATORS
•HUMAN BEING
•INSTRUMENTALITIES OF WAR
•MACHINES (PORTABLE & FIXED, EXCEPT WHEELED VEHICLES)
•METAL ITEMS, NEC
•MINERAL ITEMS, NEC
•NATURAL POISONS AND TOXIC AGENTS, NEC
NOISE
•PERSONNEL SUPPORTING SURFACES (DECK, LADDER, STAGE, BROW, PLATFORM)
•PLASTIC ITEMS, NEC
•PUMPS, ENGINES, TURBINES (NOT ELEC.)
•RADIATING SUBSTANCES AND EQUIPMENT (USE ONLY FOR RADIATION INJURIES)
•SCRAP, DEBRIS, WASTE MATERIAL, ETC., NEC (EXCEPT RADIOACTIVE)
•SHIP STRUCTURE - PARTS
•SPORTS
•TEMPERATURE (ATMOSPHERIC, ENVIRONMENTAL)
•TEXTILE ITEMS, NEC
•VEHICLES, (AIR, LAND, SEA) INCLUDING MILITARY AND INDUSTRIAL
WATER AND STEAM
•WOOD ITEMS, NEC
•MISCELLANEOUS, NEC
UNDETERMINED
•OTHER, NEC

BLOCK 21. KIND OF ACCIDENT

•STRUCK AGAINST
•STRUCK BY
•FALL OR JUMP FROM ELEVATION
•FALL OR JUMP ON SAME LEVEL
•CAUGHT IN, UNDER, OR BETWEEN
BITE OR STING, VENOMOUS AND NON-VENOMOUS
•RUBBED, ABRADED, PUNCTURED OR CUT
BODILY REACTION OR MOTION
•OVEREXERTION
•CONTACT WITH
UNDETERMINED
•OTHER, NEC

BLOCK 22. HAZARDOUS CONDITION

•DEFECT OF THE AGENCY OF ACCIDENT
•DRESS OR APPAREL HAZARD
•IMPROPER ILLUMINATION
•IMPROPER VENTILATION
•ENVIRONMENTAL HAZARD, NEC
•HAZARD OF OUTSIDE WORK ENVIRONMENT – OTHER
•INADEQUATELY GUARDED
•PLACEMENT HAZARD
•PUBLIC HAZARD
UNDETERMINED
NO HAZARDOUS CONDITION
•HAZARDOUS CONDITION, NEC

BLOCK 24. UNSAFE ACT

•WORKING ON MOVING OR DANGEROUS EQUIPMENT
•DRIVING ERRORS BY VEHICLE OPERATOR
•FAILURE TO USE PERSONAL PROTECTIVE EQUIPMENT
FAILURE TO WEAR SAFE PERSONAL ATTIRE
•FAILURE TO SECURE OR WARN
HORSEPLAY AND SKYLARKING
QUARRELING OR FIGHTING
•IMPROPER USE OF EQUIPMENT
•IMPROPER USE OF HANDS OR BODY PARTS
INATTENTION TO FOOTING OR SURROUNDINGS
•FAILURE TO USE SAFETY DEVICES
•OPERATING OR WORKING AT UNSAFE SPEED
•TAKING UNSAFE POSITION OR POSTURE
•UNSAFE PLACING, MIXING, COMBINING, ETC.
•USING UNSAFE EQUIPMENT
•OTHER UNSAFE ACTS, NEC
UNDETERMINED
NO UNSAFE ACT
NEC - NOT ELSEWHERE CLASSIFIED

BLOCK 25. UNSAFE PERSONAL FACTOR

UNDER INFLUENCE DRUG/ALCOHOL
FATIGUE
ILLNESS
•IMPROPER ATTITUDE
•LACK OF KNOWLEDGE OR SKILL
•BODILY DEFECTS
UNDETERMINED
NO UNSAFE PERSONAL FACTOR
•OTHER UNSAFE PERSONAL FACTOR, NEC

• SPECIFY/DETAIL

0-33096

29.52

Figure 1-11.–Instructions for Accidental Injury/Death Report (Back).

3. Unsafe Act. Was the crewmember operating a machine without proper authorization or working at an unsafe speed, that is, too fast or too slow? Was a safety device made inoperative, that is, blocked out or removed? Was a load made unsafe or were tools or equipment put in an unsafe place where they would fall? Did someone fail to wipe oil, water, grease, paint, etc., from working surfaces? Did the injured crewmember take an unsafe position of posture, or lift with a bent back or while in an awkward position, or lift jerkily, or ride in an unsafe position on a vehicle, or use improper means of ascending or descending? Was the injury caused by failure to wear the provided safe attire or personal protective devices, such as goggles, gloves, masks, aprons, or safety shoes?

4. Unsafe Personal Factor. Was the person absent-minded or inattentive, unaware of safe practices, unpracticed, or unskilled, unable to recognize or appreciate the hazards? Did the person fail to understand instructions, regulations, or safety rules, willfully disregard instructions or safety rules, have a bodily defect, such as poor eyesight, defective hearing, or a hernia?

5. Type of injury. Was the injury sustained a cut, bruise, sprain, strain, hernia, or fracture?

6. Part of Body affected. Did the injury involve an arm, leg, ribs, feet, fingers, head, etc?

These categories suggest some of the things (not all) you must investigate and report when accidents occur. Remember there are some questions in these categories that request medical information which can only be obtained from a doctor. Each accident is different, and each should be investigated and judged on its own merits. Do not jump to conclusions. Start each investigation with an open mind. The most important reason for any accident investigation is prevention of a similar accident.

INSPECTING NEW CONSTRUCTION, WORK AREAS, AND EXISTING STRUCTURES

Having proved yourself capable of handling responsibility, you may be called upon at times to serve as a construction/maintenance inspector. As the inspector, you are constantly in contact with other people which calls for an understanding of human relations. You must be tactful and courteous in dealing with others. In criticizing, for example, do so constructively and without causing resentment. Avoid showing any favoritism or partiality, and particularly avoid making statements or taking actions that might discredit other supervisors in the presence of their subordinates. You must be absolutely honest in your dealings with others. Integrity is a fundamental requisite. You must be trustworthy, loyal, diligent, and punctual. You must be dignified, steady, and poised in all your actions. When your job involves supervising others, be firm but fair in handling subordinates. Maintain self-respect and win the respect of all your associates, keeping in mind that a harmonious relationship is more successful than one hampered by friction and discord.

Bear in mind that the subject of inspections is broad in scope; therefore, no attempt is made here to point out the individual items to be covered in an inspection but rather to acquaint you with the duties and techniques employed by construction/maintenance inspectors.

CONSTRUCTION INSPECTOR

The prime function and responsibility of the construction inspector is to assure that the work is performed in accordance with drawings and specifications. The requirements are usually—but not always—sufficiently exacting to necessitate high standards of quality, both in materials and workmanship. In the case of temporary or emergency construction, quality requirements may be lowered intentionally. You, therefore, must be careful to ascertain that the work is of the required quality, but you also must be equally careful not to demand a quality of work superior to that required.

In some cases, the specifications for a project establish definite tolerances over and under the exact measurements that will be accepted. You then only have to verify that the work is within these tolerances. In some phases of the work, however, tolerances cannot be fixed and you must exercise good judgment in deciding whether or not standards, such as plumb and level, are met. Other times, you must decide whether the degree of accuracy is acceptable. For example, structural framing that has to be true within 1/16 inch. In any case, you should have the practical knowledge of the grades of workmanship.

It is important that you make clear at the outset of the work what will be expected. Follow up by making sure that the early phases of work fulfill your expectations. Usually, the standards of accuracy established and enforced during the first few days of work will set the pattern for the rest of the work. Be consistent in setting standards. Also, be reasonable but not lenient.

Inspection of temporary construction must be limited to that sufficient to assure that the work is adequate and safe for the purpose. You should, however, be alert to note any defective construction, unsound materials, possible weaknesses, and hazards, and call them to the attention of your superior.

You are responsible for the effective application of the safety program for projects to which assigned. The responsibility covers the prevention of accidents causing physical injury or property damage. If you find it difficult to correct or prevent a hazard or avoid an unsafe practice, immediately report to your superior for proper action and/or guidance.

Another important and rather difficult phase of inspection is checking a project as it nears completion to make sure that every item required for its completion has actually been provided. Use a checkoff system for this purpose and act early enough so there will be time for delivery and installation of items overlooked. Acting promptly is essential in cases where long lead times exist between ordering and delivery of critical items of material and equipment. Maintain a strict watch over cleanup items, particularly where the work of an early stage is covered up later on.

You may be responsible for maintaining accurate and detailed records of performance of the work and related matters. Make sure that these records are not only complete and factual, but clearly presented.

INSPECTING WORK AREAS, TOOLS, AND EQUIPMENT

When inspecting work areas, tools, and equipment, you should endeavor to see that all necessary precautions are taken to insure the safety of personnel. Some pointers that will aid you in making safety inspections of work areas, tools, and equipment are given below. You may also find these pointers useful in supervising construction operations.

Work Areas

Watch carefully for potential hazards and unsafe conditions. Work areas should be kept clean and orderly at all times. Oily rags and debris should be disposed of in approved safety containers.

Insure that equipment is arranged to permit working on material with a minimum of handling and so that work can flow in an orderly and logical sequence. In addition, see that clearance around the equipment is ample to prevent congestion and avoid interference with operation of other equipment.

Make sure materials are properly stored and walkways are kept clear. Materials should be piled so that they cannot roll, fall, tumble, or be blown over. Small parts, tools, or equipment–such as bolts, nuts, and wrenches–should not be left lying around where someone may fall over them.

Insure that planks, timbers or blocks containing projecting nails are removed immediately from the jobsite or placed in orderly piles where personnel are not likely to stumble or fall over them.

Check carefully to see that individuals observe all applicable safety precautions in performing their duties. In doing so, insure that personnel wear personal protective apparel, such as goggles, safety belts, helmets, gloves, and safety shoes, on jobs where required. See that safety equipment, such as safety screens and ventilating equipment, is used on operations where required.

Make sure that signs or signals are placed where necessary to provide proper and adequate warning of hazards. Signs should be removed as soon as the hazards have been eliminated.

Tools and Equipment

Insure that defective or damaged tools are not used, and that they are repaired or disposed of immediately. Wooden tool handles must be free of slivers or other defects. Mushroomed and burred heads on striking tools must be ground down. Gripping surfaces must be free of grease, oil, and other slippery substances.

Make sure that electric-powered portable tools are grounded and operated safely. Operators of drills, reamers, and other rotating tools must not be allowed to wear clothing with free ends, neckties, or gloves.

See that power machines are operated only by qualified personnel; that guards are kept in place during operation of machines; and that hands, as well as tools, are kept clear of all moving parts of a machine while it is in operation.

See that tools are returned to their proper place of storage when no longer needed on the job. Tools left lying around on benches, near machines, and on floors and ladders cause accidents–and get lost.

MAINTENANCE INSPECTOR

However well a structure is constructed initially, proper maintenance and repairs are necessary from time to time to keep it in first-class condition. An effective maintenance inspection will disclose whether specific types of maintenance or repairs are needed on buildings or other structures. The maintenance program should be designed to (1) promptly detect deficiencies and damages, and (2) expeditiously perform economical and workmanlike repairs. These requirements are essential if the maintenance standards are to be achieved.

Detection is provided by inspection of facilities at regular scheduled frequencies by qualified inspectors. The inspection program should also include emergency inspections prior to and following unusual and severe storms where high velocity winds, abnormal tides, and heavy wave action have been experienced; when heavy snowstorms and extremely low temperatures are anticipated or experienced; and after the occurrence of any operational hazards. In some instances, an inspection will turn up minor defects which can be corrected promptly and, as a result, prevent the occurrence of major defects requiring extensive repairs. As an EO, you may be called upon to conduct maintenance inspections at Navy activities. This is a responsible job and one that should be assigned to well qualified personnel.

The types of structures that you inspect will depend upon the types available at your activity. Let us reemphasize, too, that this instruction is not intended to list items that should be checked during an inspection of a specific type of structure. Detailed information applicable to the maintenance inspection of structures can be found in the appropriate MO's, which are published by NAVFAC and listed in the *NAVFAC Documentation Index*, NAVFAC P-349.

At some activities, forms may be available on which a checklist is provided showing major items to be covered in the inspection of the structure concerned. These forms may be prepared locally, and therefore may differ from one activity to another. At times, of course, forms may not be available and you will have to depend upon past experience in building and construction, as well as sound judgment, in determining what to look for in the inspection.

After completing an inspection, you may have to make a written report on your findings. You may also make recommendations on the type and extent of repairs needed to correct certain defects. You must remember that each inspection is important and should be done carefully, thoroughly, and with safety in mind.

OFFICIAL CORRESPONDENCE

On occasion you may be expected to compose official correspondence, perhaps only from brief notes or oral instructions. Official correspondence in its true sense encompasses all recorded communications, including messages.

In general, official outgoing correspondence is prepared only in the rough at the department level and is "chopped" to the executive officer or the administrative assistant for approval and preparation in the smooth for the commanding officer's signature.

STANDARD NAVAL LETTERS

Figure 1-12 and figure 1-13 illustrate the standard naval letter in finished form. When preparing correspondence in the rough, always double space the text to allow for corrections or insertions by reviewing officers. Before starting the letter, find out from the drafting officer (you may physically prepare the draft, but the officer is responsible for the finished product) whether it is to be classified. If so, the classification must appear near the top and bottom of each page. Note the identification and indentation of paragraphs and subparagraphs. The drafting officer will have to determine who the "via" and "copy to" addressees (if any) are to be. There are two important rules of thumb: (1) references shown in the heading of the letter should be mentioned (in chronological order) within the text at least once, and (2) unless they are very closely related, do not cover two subjects in one letter. The latter practice can result in administrative confusion when replies are required.

When preparing correspondence, bear in mind that the usual purpose of Navy mail is to provide the reader with concisely stated information. If you turn out a confused, rambling, repetitious, or needlessly lengthy masterpiece of semantic purity, you only create an editing chore for the drafting officer–and you may wind up doing the whole thing over.

Before starting the letter, be sure you understand exactly what the letter is to accomplish. Then its organization becomes essentially simple. The first paragraph should state the purpose of the letter; the following paragraph(s) explain circumstances and state the action (give orders, make requests, give consent, or refuse permission).

When the letter is in answer or closely related to another letter, the first sentence should refer to that letter. For example: "1. Reference (a) requested information about the allowance lists for the next 3 fiscal years. Reference (b) pointed out that such information is available for only 2 years in advance. . ."

The usual causes of confusion and rambling in a letter are–

1. Failure to follow the basic pattern (purpose, circumstances, action).
2. Inclusion of more than a single idea in a sentence, more than one central thought in a paragraph, or more than a single subject in the letter.
3. Failure to consider the readers (can the letter be misinterpreted?).

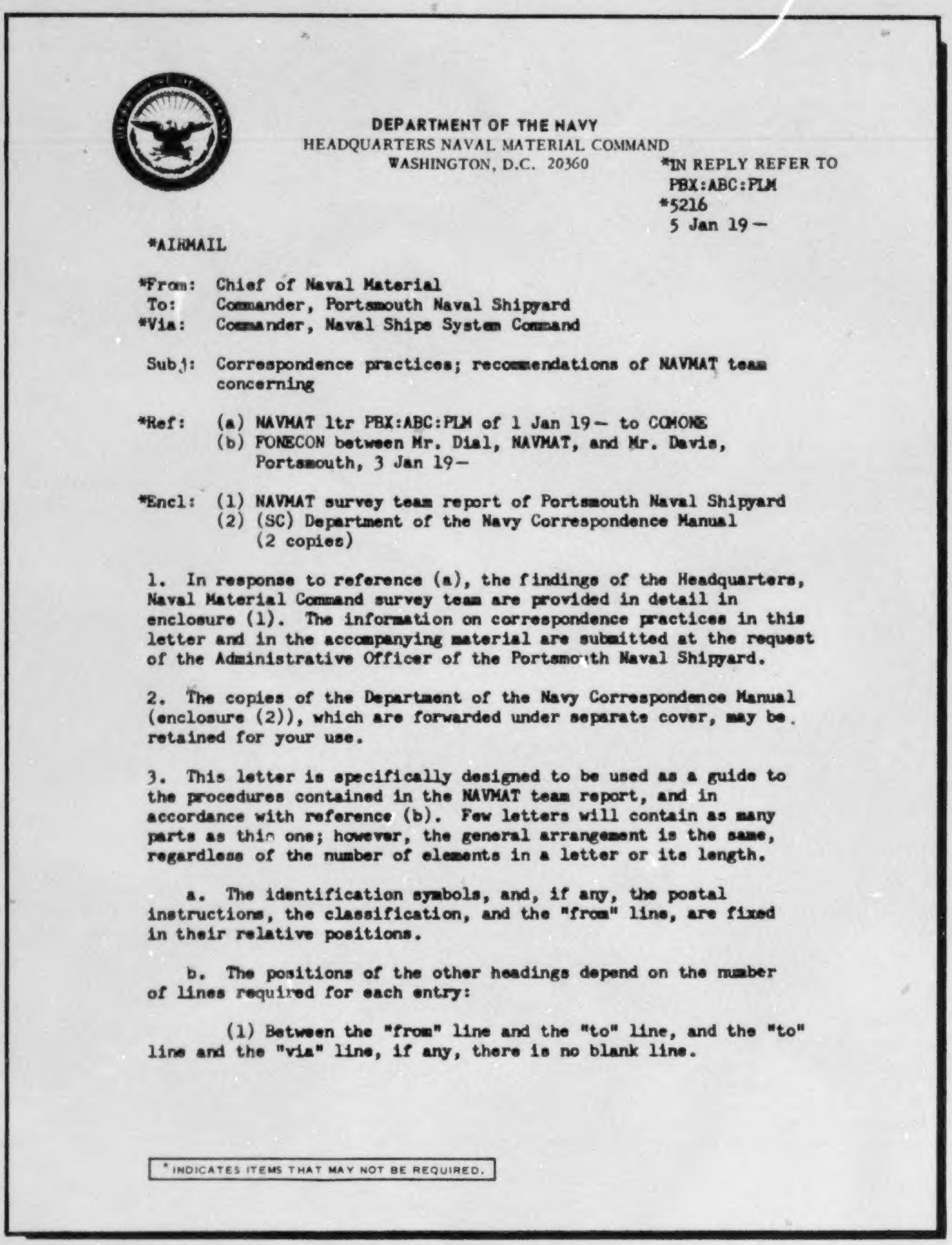
In letters of average length, each significant unit may be one paragraph, although there is no rule about this; explaining the reasons why something should be done may take more than one paragraph, while other letters are so simple that a single paragraph makes up the entire body. The important thing for the writer is to (1) arrange the units in what seems the most satisfactory order, (2) complete each unit before moving on to the next, and (3) maintain continuity by providing transition from one unit to another.

When you prepare the first draft, don't worry too much about the finished product. Get something on paper. You can go over it later for errors, clarity, and good order. If possible, let the first draft cool for awhile and occupy your mind with other matters before going over it again. This practice tends to make you more objective–you will find flaws not apparent to you earlier. Delete unneeded words, cut down the big ones, take out the intensives (very much, extremely), eliminate unnecessary introductory phrases such as "it is to be noted" and "we call your attention to the fact that," and avoid repetition.

MEMORANDA

Although there are variations of the form of naval correspondence called a memorandum, the one most frequently utilized is the simple "From-To" type between subordinates within the same activity.

A preprinted Department of the Navy Memorandum (short or long) form is available, or you may use a plain or letterhead (when the memorandum is addressed outside the organization) sheet of paper. When using other



DEPARTMENT OF THE NAVY
HEADQUARTERS NAVAL MATERIAL COMMAND
WASHINGTON, D.C. 20360

*IN REPLY REFER TO
PBX:ABC:PLM
*5216
5 Jan 19—

*AIRMAIL

*From: Chief of Naval Material
To: Commander, Portsmouth Naval Shipyard
*Via: Commander, Naval Ships System Command

Subj: Correspondence practices; recommendations of NAVMAT team concerning

*Ref: (a) NAVMAT ltr PBX:ABC:PLM of 1 Jan 19— to COMONE
(b) FONECON between Mr. Dial, NAVMAT, and Mr. Davis, Portsmouth, 3 Jan 19—

*Encl: (1) NAVMAT survey team report of Portsmouth Naval Shipyard
(2) (SC) Department of the Navy Correspondence Manual (2 copies)

1. In response to reference (a), the findings of the Headquarters, Naval Material Command survey team are provided in detail in enclosure (1). The information on correspondence practices in this letter and in the accompanying material are submitted at the request of the Administrative Officer of the Portsmouth Naval Shipyard.

2. The copies of the Department of the Navy Correspondence Manual (enclosure (2)), which are forwarded under separate cover, may be retained for your use.

3. This letter is specifically designed to be used as a guide to the procedures contained in the NAVMAT team report, and in accordance with reference (b). Few letters will contain as many parts as this one; however, the general arrangement is the same, regardless of the number of elements in a letter or its length.

a. The identification symbols, and, if any, the postal instructions, the classification, and the "from" line, are fixed in their relative positions.

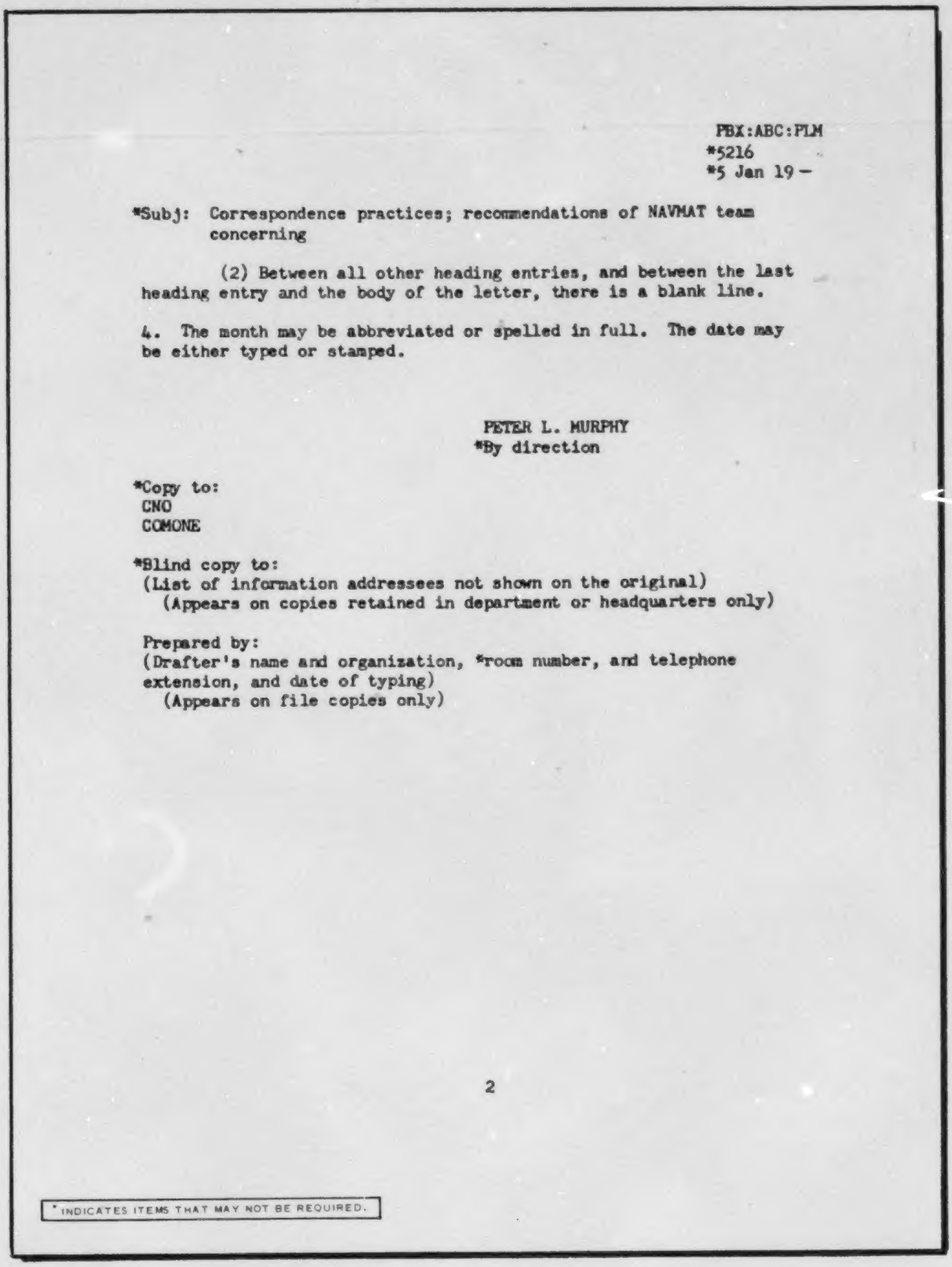
b. The positions of the other headings depend on the number of lines required for each entry:

(1) Between the "from" line and the "to" line, and the "to" line and the "via" line, if any, there is no blank line.

*INDICATES ITEMS THAT MAY NOT BE REQUIRED.

95.17

Figure 1-12.—Standard naval letter.



PBX:ABC:PLM
*5216
*5 Jan 19 –

*Subj: Correspondence practices; recommendations of NAVMAT team
concerning

(2) Between all other heading entries, and between the last heading entry and the body of the letter, there is a blank line.

4. The month may be abbreviated or spelled in full. The date may be either typed or stamped.

PETER L. MURPHY
*By direction

*Copy to:
CNO
COMONE

*Blind copy to:
(List of information addressees not shown on the original)
(Appears on copies retained in department or headquarters only)

Prepared by:
(Drafter's name and organization, *room number, and telephone extension, and date of typing)
(Appears on file copies only)

2

*INDICATES ITEMS THAT MAY NOT BE REQUIRED.

95.17

Figure 1-13.–Standard naval letter–Continued.

than the preprinted form, type "MEMORANDUM" in capital letters at the left margin. Two spaces below that type "From:" and proceed as you would for a naval letter. For very informal communications, memoranda may be handwritten.

Variations of the "From-To" style include the "Memorandum For" and "2-Way Letter-Memo" types. The former is used between high-level officials within the Department of Defense. The "2-Way" incorporates the efficiencies of a preprinted format and preinserted carbon; it is employed only for communications that require a reply.

SPEEDLETTERS

A speedletter is used for an urgent communication that does not require electrical transmission. It is prepared on a standard, preprinted form prominently marked across the top with NAVAL SPEEDLETTER in large letters. Unlike other types of correspondence, an extra copy is provided the addressee so that they may reply on the speedletter (copy) itself.

The main purpose of the speedletter format is to call attention to the communication so that it will be given priority handling by the addressee. To this end, a special speedletter envelope is available to insure that mail handlers give the speedletter immediate attention. If a regular envelope must be used, it should be conspicuously marked with the word "SPEEDLETTER" in capital letters.

With some variations, a speedletter is prepared in much the same way as a naval letter (except that if time is critical, the speedletter may be handwritten). Identifying blocks take care of most of the information normally placed at the top of a standard letter down through the "To" line. Therefore, unless "Subj" and "Ref" lines are used, the writer places nothing in the textual portion of the speedletter form except the text itself, the signature, a list of enclosures if any, and, if needed, downgrading and classification data.

MESSAGES

A message is a written thought or idea, expressed briefly and to the point, and prepared for transmission by the most suitable means of telecommunication.

The Originator of a message is the command by whose authority the message is sent. The Drafter—usually the communications officer or a department head—is the person who actually composes the message for release. The Releasing Officer authorizes transmission of the message for and in the name of the originator. Usually the commanding officer is releasing officer, but may delegate the releasing authority.

Basic Message Format

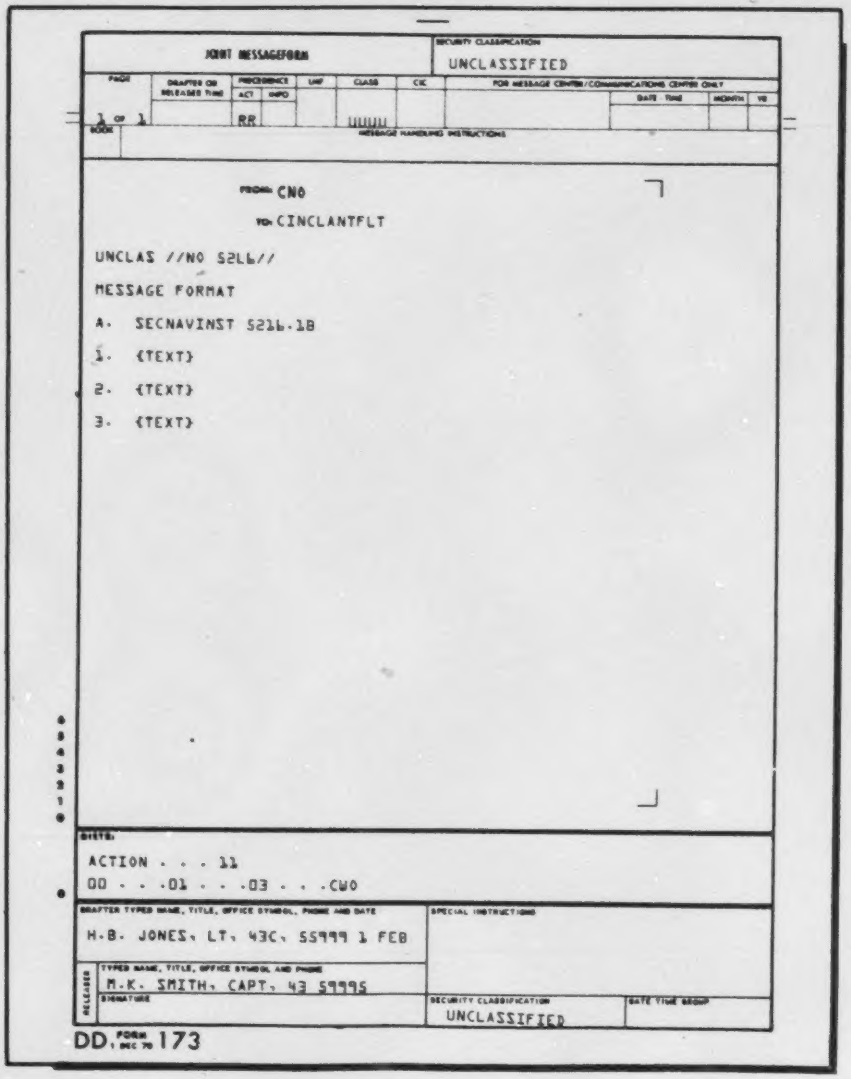
With a few exceptions, military messages sent by electrical telecommunications are arranged in a basic naval message format. See figure 1-14.

Communications requiring expeditious delivery are prepared for transmission as brief, concise messages with a message heading and a message text.

Heading

Figure 1-14 shows which parts of the heading must be completed. Although you do not fill in the date/time group block, you need to understand how to read this information.

The date-time group is expressed as six digits with a zone suffix, plus an abbreviated month and a two-digit year. The first pair of digits (080005Z AUG 79) denotes the date of the month, the second pair (080005Z AUG 79) the hours, and the third pair (080005Z AUG 79) the minutes, followed by a capitalized letter which indicates the time zone. For standardization all naval communications use Greenwich (Z) time. Duplicate date-time groups should not be used by the same originator during any one 24-hour period. Normally, the time included in the date-time group is the time at which the originator delivered the message to the communications center for transmission. All



JOINT MESSAGEFORM

SECURITY CLASSIFICATION: UNCLASSIFIED

PAGE	DRAFTER OR RELEASER TIME	PRECEDENCE ACT	PRECEDENCE INFO	LMF	CLASS	CIC	FOR MESSAGE CENTER/COMMUNICATIONS CENTER ONLY	DATE-TIME	MONTH	YR
1 OF 1		RR			UUUUU					

BOOK

MESSAGE HANDLING INSTRUCTIONS

FROM: CNO

TO: CINCLANTFLT

UNCLAS //N0 5216//

MESSAGE FORMAT

A. SECNAVINST 5216.1B

1. (TEXT)

2. (TEXT)

3. (TEXT)

DISTR:

ACTION . . . 11

00 . . .01 . . .03 . . .CWO

DRAFTER TYPED NAME, TITLE, OFFICE SYMBOL, PHONE AND DATE

H.B. JONES, LT, 43C, 55999 1 FEB

SPECIAL INSTRUCTIONS

RELEASER

TYPED NAME, TITLE, OFFICE SYMBOL AND PHONE

M.K. SMITH, CAPT, 43 59995

SIGNATURE

SECURITY CLASSIFICATION: UNCLASSIFIED

DATE TIME GROUP

DD FORM 1 DEC 70 173

31.47

Figure 1-14.—Format for naval message.

numerals in abbreviated titles used in naval messages are spelled out.

Text

The text of a naval message is prepared as shown in figure 1-14. Notice that the message paragraphs are numbered, except for short, one-paragraph messages. Subparagraphs are indented and lettered or numbered as appropriate. If the message is classified, it is marked with the proper downgrading/declassification markings. The number of characters and spaces on a line is sixty-nine.

Short titles or abbreviations are not used in the text if the message is addressed to a Member of Congress, a commercial concern, or a nonmilitary address.

The punctuation marks that may be used to enhance clarity within the message text follow:

Hyphen (-)
Question mark (?)
Colon (:)
Dollar sign ($)
Apostrophe (')
Ampersand (&)
Parentheses (left and right) ( )
Period (.)
Comma (,)
Vergule (or slant) (/)
Quotation mark (")
Number symbol (#)

The punctuation that may NOT be used in a naval message follows:

"At" sign (@)
Percent (%)
Fractions (1/2, 1/4, et cetera)
Asterisk (*)
Underscore (_)
Cent sign (¢)

TRAINING

The training program of each battalion is formulated to provide the personnel with the skills needed to accomplish the battalion's current and mobilization mission. The program is crafted in accordance with the pattern, priorities, and tempo established by the Commanding Officer. The program covers many phases, from orientation courses to special technical courses. It depends upon such factors as operational commitments, policies, and directives from higher authority; experience and previous training of the personnel; and training facilities available. Although much of the construction training will be provided by Class A or C Schools as well as Special SEABEE Training Courses, additional skill and experience must be acquired in the battalion.

As a supervisor, you must emphasize the importance of training to your operators. At the same time, impress upon them the importance of using the correct terminology and/or technical language common to the EO rating. In so doing, your operators should learn more readily and also retain a more detailed picture of the functions and operations of their job.

ORGANIZATION

Navy Regulations state that the Executive Officer will supervise and coordinate the work, exercises, training, and education of personnel of the command. As Chief Staff Officer, the executive officer supervises the training of battalion officers, coordinates the planning and execution of the training program and, when necessary, acts to correct deficiencies in the program. The Plans and Training Officer is the principal assistant to the Chief Staff Officer.

Company Commanders are directly responsible for the training of their company personnel and for the fulfillment of training goals as established by the Commanding Officer. They help formulate training programs; supervise the training of subordinate officers; and direct the technical, military, and general training of their companies. The battalion service department heads are responsible for the individual training of personnel in the departments. They conduct training for advancement and administer the OPNAV-sponsored general training. Platoon leaders observe closely the training progress of their personnel. They directly supervise on-the-job construction and military training. All petty officers assume the responsibility for training their crews and must be able to conduct effective training courses utilizing lectures, discussions, project work, and so on.

The Plans and Training Officer is generally assisted by a permanently assigned staff of three or four petty officers and by additional personnel on a part-time basis as necessitated by the battalion's formal training workload. This group is generally headed by a chief petty officer and its members often function as training instructors. Although responsible for the entire battalion training program, this group is primarily concerned with the formulation and administration of the formal military training program and that part of the technical training program which includes advanced base construction and disaster recovery. The other aspects of the technical training and general training programs are formulated and administered within each company, but should correspond to the general guidelines established by the Plans and Training Officer.

In the Amphibious Construction Battalion, the Training Officer may serve as assistant to the Operations Officer. He arranges and schedules all formal training of officers and enlisted men, performing essentially the same duties as the Plans and Training Officer of the Naval Mobile Construction Battalion.

In general, training should be consistent with the following guidelines:

1. It must be closely integrated and coordinated with daily operations of the battalion. The plan and organization for training that is adopted must not interfere with essential construction functions.

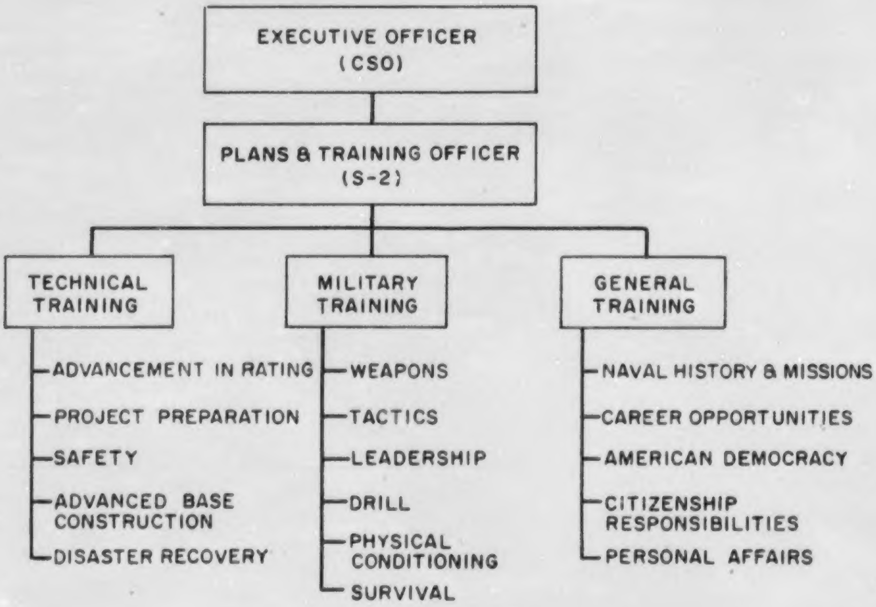
2. Notwithstanding the guideline just listed, the construction schedule should not be so inflexible that it overlooks opportunities for training that might even expedite the construction schedule.

3. Maximum advantage should be taken of the opportunity to derive training benefits from routine operations.

A typical battalion training organization chart is illustrated in figure 1-15.

THE PERSONNEL READINESS CAPABILITY PROGRAM

The Personnel Readiness Capability Program (PRCP) is a management tool which was developed in the mid-1960's by the staff of the Commander, Construction Battalions, U.S. Atlantic Fleet and subsequently implemented throughout the active and reserve Naval Construction Force (NCF). Its purpose is to provide managers at all levels of the NCF with


EXECUTIVE OFFICER
(CSO)
PLANS & TRAINING OFFICER
(S-2)
TECHNICAL TRAINING
MILITARY TRAINING
GENERAL TRAINING
ADVANCEMENT IN RATING
PROJECT PREPARATION
SAFETY
ADVANCED BASE CONSTRUCTION
DISASTER RECOVERY
WEAPONS
TACTICS
LEADERSHIP
DRILL
PHYSICAL CONDITIONING
SURVIVAL
NAVAL HISTORY & MISSIONS
CAREER OPPORTUNITIES
AMERICAN DEMOCRACY
CITIZENSHIP RESPONSIBILITIES
PERSONAL AFFAIRS

143.133

Figure 1-15.—Battalion training organization chart.

timely personnel information which will increase their capabilities in planning, decision making, and control.

Prior to the implementation of the PRCP, personnel information was kept on an "as required" basis by various members of the unit in personal notebooks, files, and records. This information was collected as managment required it to determine military and construction capabilities, training requirements, logistics support, etc. The collecting of this information was usually a time-consuming, laborious task that required a piecemeal inventory of the command's capabilities or requirements. Another way of getting this information was through the use of rough estimates. Neither way however, produced the accuracy or rapid response desired. Implementation of the PRCP helped to do so by establishing standard procedures for identifying, collecting, processing, and utilizing this information.

The Personnel Readiness Capability Program requires each participating command to gather, and continuously update, information on each member of the unit. Most of this information concerns skills acquired through actual job experience or through some type of training program. Other information such as expiration of enlistment or rotation date, is required for accurate planning. The gathering of this other information is called a SKILL INVENTORY.

SKILL INVENTORY

An accurate and current skill inventory is the backbone of the PRCP. Without it, the reliability of any planning based on information stored in the PRCP DATA BANK is questionable. Presently, all PRCP skills and other data are based on requirements established by COMCBPAC and COMCBLANT and promulgated in their joint instruction of the 1500.20 series. Additionally, these skills have been conveniently classified into five major categories:

(1) Individual General Skills. These are essentially nonmanipulative skills (knowledge) related to two or more ratings, such as construction inspection, planning and estimating, and safety inspection.

(2) Individual Rating Skills. These are primarily manipulative skills associated with one of the seven Occupational Field 13 (Construction) Ratings. Some examples are: light frame construction for Builder, cable splicing for Construction Electrician, and shore based boiler operation for Utilitiesman.

(3) Individual Special Skills. These are technical skills performed by several ratings, including those other than Occupational Field 13's. For example: forklift operation, ham radio operation, or typing.

(4) Military Skills. These are further classified into two subcategories: General Military Requirements and SEABEE Combat Readiness. Examples are disaster recovery training and mines and booby traps, respectively.

(5) Crew Experience Skills: These are gained by working with others on specific projects. Most of these projects are related to advanced base construction, such as steel tank erection, pile driving, and SATS installation.

A skill inventory has three principal steps. First, each skill is closely defined so that each person will give it the same meaning. Second, a standard procedure for obtaining the information is developed. This procedure helps to insure that the information, regardless of where it is collected or by whom, will meet certain standards of acceptability. The third and last step is the actual collection of the skill data and includes the procedures for submitting the data to the data bank.

Skill Definitions

A book of standard SKILL DEFINITIONS, called *Book 1–PRCP Skill Definitions*, contains a definition for every skill identified in the Personnel Readiness Capability Program. Each definition has been jointly approved by COMCBLANT, CONCBPAC, and CNRT (Chief of Naval Reserve Training) and is applicable to the entire Naval Construction Force.

PRCP Interviewer's Standards and Guides

The skill definitions alone do not contain sufficiently detailed information to accurately classify people, nor do they provide any classification procedures. Recognizing this, the Civil Engineer Support Office (CESO) conducted special SEABEE workshops where the *PRCP Interviewer's Standards and Guides* were developed under the guidance of CESO. The *Guides* contain a detailed TASK ANALYSIS of each skill definition as well as standard procedures for its use. The *PRCP Interviewer's Standards and Guides* are the principal tools used in collecting skill data. They can be used two ways: (1) by following the interviewing procedures in each guide, a trained interviewer is able to classify people to a predetermined skill level within an acceptable degree of uniformity; and (2) by having a thorough knowledge of the tasks required of each skill, anyone so authorized can classify others to an appropriate skill level by actually observing them perform the tasks, either in training or on the job.

Skill information obtained from interviewing or observing is submitted to the Facilities Systems Office (FACSO), Port Hueneme, California on a special form known as a TRANSCRIPT MASTER (Fig. 1-16). This form, which consists of multiple sheets of carbon sensitive paper, is preprinted with every skill identified in the PRCP. Normally, it is only necessary to mark the appropriate skill levels attained, send a copy to FACSO–where the data bank is maintained–and retain a designated copy at the unit level. Complete instructions and information for using the transcript master, as well as other PRCP data processing information, can be obtained from the training officer of units participating in the program.

As an E-6 crew/squad leader, you are directly responsible for using the *PRCP Interviewer's Standards and Guides* to interview your personnel (or others) and to provide the initial information for the PRCP data bank. Subsequent UPDATING of this initial information for each person is based on either performance on the job (which you observe) or performance at a school. New personnel, however, and others returning from long periods of certain types of shore duty, may require interviewing.

PRCP INTERVIEWS

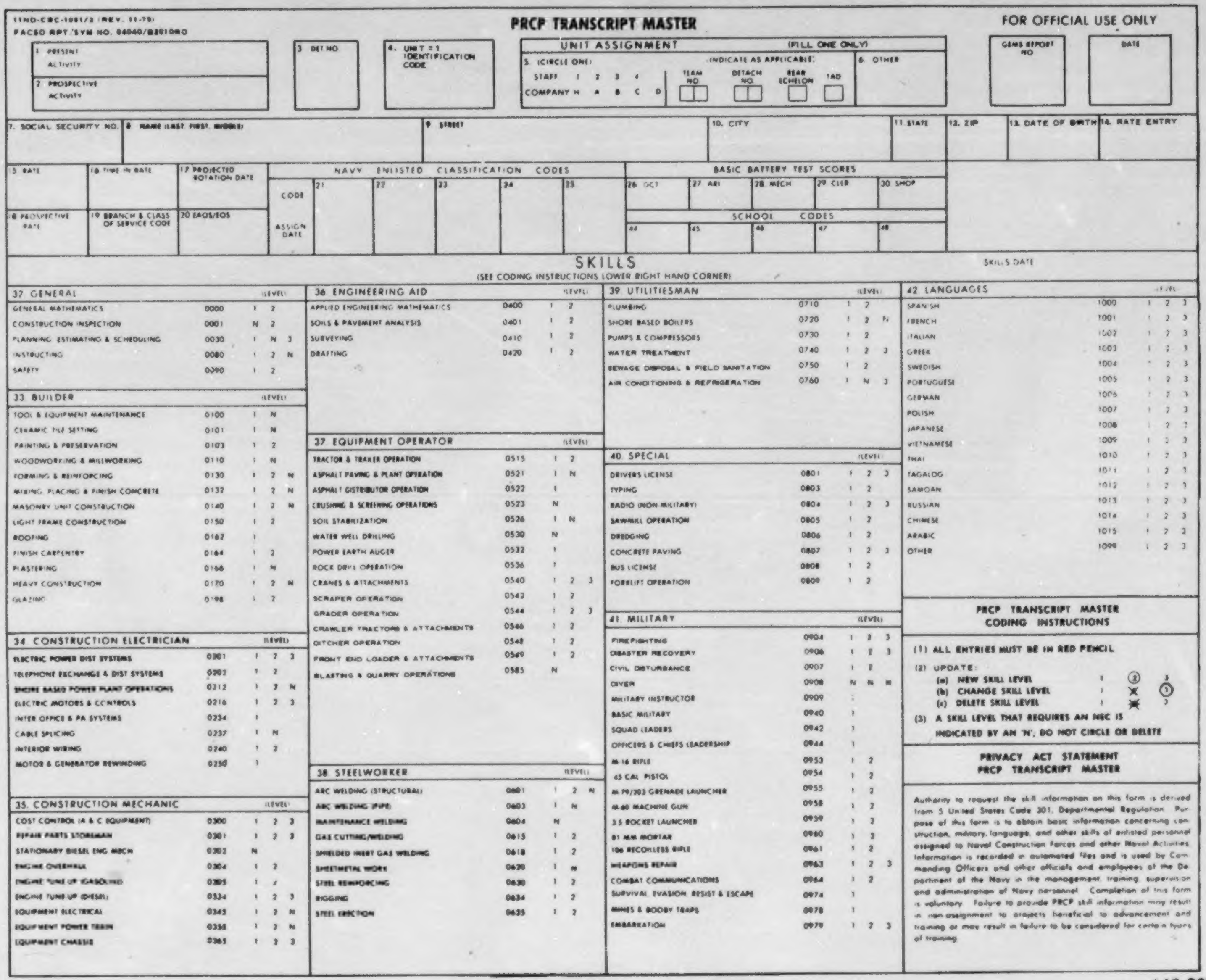
There are two types of PRCP interviews. The first and most important is the INDIVIDUAL RATING SKILL INTERVIEW. The second type is simply called OTHER INTERVIEWS. Both types require the use of the *PRCP Interviewer's Standards and Guides.*

Rating Skill Interviews

The individual rating skill interview must be conducted by an experienced and knowledgeable supervisor. The interviewer uses a discussion technique to classify other SEABEEs in the skill levels of the various individual rating skills. This technique requires a thorough understanding of the skills and tasks explained in the interviewing guides. Since few individuals possess the talent required to interview in all the skills of a rating, the interviewers must be mature enough to recognize their own limitations and be willing to seek assistance from others in their rating.

Other Interviews

Other interviews are used to classify people into the individual general and special skills, military skills, and crew experience. With only a few exceptions, these skills do not require an experienced interviewer; and in many cases, skill levels can be assigned to individuals on the basis of their service or training record. This should be done whenever possible to cut down on interviewing time. Then, when the person is in for interviewing, it will be just a matter of verification or of updating.



11ND-CBC-1081/2 (REV. 11-79)
FACSO RPT SYM NO. 04040/B2010RO

PRCP TRANSCRIPT MASTER

FOR OFFICIAL USE ONLY

1 PRESENT ACTIVITY
2 PROSPECTIVE ACTIVITY
3 DET NO
4. UNIT = 1 IDENTIFICATION CODE

UNIT ASSIGNMENT (FILL ONE ONLY)
5. (CIRCLE ONE)
STAFF 1 2 3 4
COMPANY H A B C D
INDICATE AS APPLICABLE: TEAM NO ☐☐ DETACH NO. ☐☐ REAR ECHELON ☐ TAD ☐
6. OTHER

GEMS REPORT NO
DATE

7. SOCIAL SECURITY NO.
8 NAME (LAST, FIRST, MIDDLE)
9 STREET
10. CITY
11 STATE
12. ZIP
13. DATE OF BIRTH
14. RATE ENTRY
15 RATE
16 TIME IN RATE
17 PROJECTED ROTATION DATE
18 PROSPECTIVE RATE
19 BRANCH & CLASS OF SERVICE CODE
20 EAOS/EOS

NAVY ENLISTED CLASSIFICATION CODES

	21	22	23	24	25
CODE					
ASSIGN DATE					

BASIC BATTERY TEST SCORES

26 GCT	27 ARI	28 MECH	29 CLER	30 SHOP

SCHOOL CODES

44	45	46	47	48

SKILLS
(SEE CODING INSTRUCTIONS LOWER RIGHT HAND CORNER)

SKILLS DATE

32 GENERAL		(LEVEL)		
GENERAL MATHEMATICS	0000	1	2	
CONSTRUCTION INSPECTION	0001	N	2	
PLANNING, ESTIMATING & SCHEDULING	0030	1	N	3
INSTRUCTING	0080	1	2	N
SAFETY	0090	1	2	

33 BUILDER		(LEVEL)		
TOOL & EQUIPMENT MAINTENANCE	0100	1	N	
CERAMIC TILE SETTING	0101	1	N	
PAINTING & PRESERVATION	0103	1	2	
WOODWORKING & MILLWORKING	0110	1	N	
FORMING & REINFORCING	0130	1	2	N
MIXING, PLACING & FINISH CONCRETE	0132	1	2	N
MASONRY UNIT CONSTRUCTION	0140	1	2	N
LIGHT FRAME CONSTRUCTION	0150	1	2	
ROOFING	0162	1		
FINISH CARPENTRY	0164	1	2	
PLASTERING	0166	1	N	
HEAVY CONSTRUCTION	0170	1	2	N
GLAZING	0198	1	2	

34 CONSTRUCTION ELECTRICIAN		(LEVEL)		
ELECTRIC POWER DIST SYSTEMS	0201	1	2	3
TELEPHONE EXCHANGE & DIST SYSTEMS	0202	1	2	
SHORE BASED POWER PLANT OPERATIONS	0212	1	2	N
ELECTRIC MOTORS & CONTROLS	0216	1	2	3
INTER OFFICE & PA SYSTEMS	0234	1		
CABLE SPLICING	0237	1	N	
INTERIOR WIRING	0240	1	2	
MOTOR & GENERATOR REWINDING	0250	1		

35. CONSTRUCTION MECHANIC		(LEVEL)		
COST CONTROL (A & C EQUIPMENT)	0300	1	2	3
REPAIR PARTS STOREMAN	0301	1	2	3
STATIONARY DIESEL ENG MECH	0302	N		
ENGINE OVERHAUL	0304	1	2	
ENGINE TUNE UP (GASOLINE)	0305	1	2	
ENGINE TUNE UP (DIESEL)	0334	1	2	3
EQUIPMENT ELECTRICAL	0345	1	2	N
EQUIPMENT POWER TRAIN	0355	1	2	N
EQUIPMENT CHASSIS	0365	1	2	3

36 ENGINEERING AID		(LEVEL)		
APPLIED ENGINEERING MATHEMATICS	0400	1	2	
SOILS & PAVEMENT ANALYSIS	0401	1	2	
SURVEYING	0410	1	2	
DRAFTING	0420	1	2	

37 EQUIPMENT OPERATOR		(LEVEL)		
TRACTOR & TRAILER OPERATION	0515	1	2	
ASPHALT PAVING & PLANT OPERATION	0521	1	N	
ASPHALT DISTRIBUTOR OPERATION	0522	1		
CRUSHING & SCREENING OPERATIONS	0523	N		
SOIL STABILIZATION	0526	1	N	
WATER WELL DRILLING	0530	N		
POWER EARTH AUGER	0532	1		
ROCK DRILL OPERATION	0536	1		
CRANES & ATTACHMENTS	0540	1	2	3
SCRAPER OPERATION	0542	1	2	
GRADER OPERATION	0544	1	2	3
CRAWLER TRACTORS & ATTACHMENTS	0546	1	2	
DITCHER OPERATION	0548	1	2	
FRONT END LOADER & ATTACHMENTS	0549	1	2	
BLASTING & QUARRY OPERATIONS	0585	N		

38 STEELWORKER		(LEVEL)		
ARC WELDING (STRUCTURAL)	0601	1	2	N
ARC WELDING (PIPE)	0603	1	N	
MAINTENANCE WELDING	0604	N		
GAS CUTTING/WELDING	0615	1	2	
SHIELDED INERT GAS WELDING	0618	1	2	
SHEETMETAL WORK	0620	1	N	
STEEL REINFORCING	0630	1	2	
RIGGING	0634	1	2	
STEEL ERECTION	0635	1	2	

39 UTILITIESMAN		(LEVEL)		
PLUMBING	0710	1	2	
SHORE BASED BOILERS	0720	1	2	N
PUMPS & COMPRESSORS	0730	1	2	
WATER TREATMENT	0740	1	2	3
SEWAGE DISPOSAL & FIELD SANITATION	0750	1	2	
AIR CONDITIONING & REFRIGERATION	0760	1	N	3

40. SPECIAL		(LEVEL)		
DRIVERS LICENSE	0801	1	2	3
TYPING	0803	1	2	
RADIO (NON-MILITARY)	0804	1	2	3
SAWMILL OPERATION	0805	1	2	
DREDGING	0806	1	2	
CONCRETE PAVING	0807	1	2	3
BUS LICENSE	0808	1	2	
FORKLIFT OPERATION	0809	1	2	

41. MILITARY		(LEVEL)		
FIREFIGHTING	0904	1	2	3
DISASTER RECOVERY	0906	1	2	3
CIVIL DISTURBANCE	0907	1	2	
DIVER	0908	N	N	N
MILITARY INSTRUCTOR	0909	1		
BASIC MILITARY	0940	1		
SQUAD LEADERS	0942	1		
OFFICERS & CHIEFS LEADERSHIP	0944	1		
M-16 RIFLE	0953	1	2	
.45 CAL PISTOL	0954	1	2	
M-79/203 GRENADE LAUNCHER	0955	1	2	
M-60 MACHINE GUN	0958	1	2	
3.5 ROCKET LAUNCHER	0959	1	2	
81 MM MORTAR	0960	1	2	
106 RECOILLESS RIFLE	0961	1	2	
WEAPONS REPAIR	0963	1	2	3
COMBAT COMMUNICATIONS	0964	1	2	
SURVIVAL, EVASION, RESIST & ESCAPE	0974	1		
MINES & BOOBY TRAPS	0978	1		
EMBARKATION	0979	1	2	3

42 LANGUAGES		(LEVEL)		
SPANISH	1000	1	2	3
FRENCH	1001	1	2	3
ITALIAN	1002	1	2	3
GREEK	1003	1	2	3
SWEDISH	1004	1	2	3
PORTUGUESE	1005	1	2	3
GERMAN	1006	1	2	3
POLISH	1007	1	2	3
JAPANESE	1008	1	2	3
VIETNAMESE	1009	1	2	3
THAI	1010	1	2	3
TAGALOG	1011	1	2	3
SAMOAN	1012	1	2	3
RUSSIAN	1013	1	2	3
CHINESE	1014	1	2	3
ARABIC	1015	1	2	3
OTHER	1099	1	2	3

PRCP TRANSCRIPT MASTER
CODING INSTRUCTIONS

(1) ALL ENTRIES MUST BE IN RED PENCIL
(2) UPDATE:
(a) NEW SKILL LEVEL 1 ② 3
(b) CHANGE SKILL LEVEL 1 ~~2~~ ③
(c) DELETE SKILL LEVEL 1 ~~2~~ 3
(3) A SKILL LEVEL THAT REQUIRES AN NEC IS INDICATED BY AN 'N', DO NOT CIRCLE OR DELETE

PRIVACY ACT STATEMENT
PRCP TRANSCRIPT MASTER

Authority to request the skill information on this form is derived from 5 United States Code 301, Departmental Regulation. Purpose of this form is to obtain basic information concerning construction, military, language, and other skills of enlisted personnel assigned to Naval Construction Forces and other Naval Activities. Information is recorded in automated files and is used by Commanding Officers and other officials and employees of the Department of the Navy in the management, training, supervision and administration of Navy personnel. Completion of this form is voluntary. Failure to provide PRCP skill information may result in non-assignment to projects beneficial to advancement and training or may result in failure to be considered for certain types of training.

Figure 1-16.—PRCP transcript master.

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USING THE INDIVIDUAL RATING SKILL GUIDES

When assigned as an interviewer, you must obtain, read, understand, and use the *PRCP Interviewer's Standards and Guides.* The format of the *Guides* is standard. After the TITLE PAGE, you'll find the SKILL DEFINITION. Then come the TASKS which are broken down into TASK ELEMENTS. See figures 1-17 through 1-20.

Title Page

The title page serves to identify the skill and the pages which follow. For example, the sample title page in figure 1-17 identifies the Individual Equipment Operator Skill of 526, SOIL STABILIZATION. The number 526 is a numerical code for this skill. The CONTENTS can be used to insure that there are no missing pages. The skill definition will always be listed first. Directly under it will be .1 Skill Level 1. Under each skill level are the tasks for which you must interview each candidate to see if that person is qualified for that level.

Skill Definition

Figure 1-18 illustrates an individual rating skill definition. Its significant features are: a standard numerical designation and title, 526–Soil Stabilization, a statement of tasks to be performed at each level, and the identification of training courses whereby the tasks may be learned.

Each skill definition consists of one, two, or three skill levels, depending upon the complexity and number of the tasks. Each level within a given skill is more difficult to attain than the previous one; however, it has no relationship to another skill. For example, a person with Skill Level 1 in Soil Stabilization performs comparatively easy tasks, whereas a Skill Level 1 in Water Well Drilling must perform everything required in that specific area.

The purpose of the skill definition in the *Guides* is to introduce the skill material to the interviewees. In fact, you begin your interview by reading the skill definition. If the interviewees say they can do the related work, you may continue with the interview for the skill level; however, if they say they can't do the work, it is obvious that you should go on to some other skill.

Tasks and Task Elements

A TASK is a specific portion of the overall skill level. Some tasks cover relatively broad areas; others are quite specific and brief. Each task is further broken down into several smaller jobs called task elements.

A task element is a basic part of each task. When interviewing, you will use the task elements and their related ACTION STATEMENTS to determine the interviewee's qualifications.

Action statements tell you the type of information you should get from the person being interviewed. Each action statement is identified in the *Guides* by a capital letter (A, B, C, etc). The number of statements varies from task to task. The first action statement in figure 1-19 is, "A. Describe the sequence of steps of this procedure and explain the reasons for each."

To illustrate the Matrix function, refer to Task Element .01, "Conduct visual inspection." Extend a line to the right and enter the Matrix. You will find an X under column A and D and also under column F. This indicates Action Statements A, D, and F are to be applied to the Task Element .01 "Conduct visual inspection."

STEPS FOR INTERVIEWING

When interviewing, the first thing you should do is to attempt to put the interviewees as ease. A good way of doing this is to explain the purpose of the interview. For example, the interview will:

a. Let the interviewees know what they are actually expected to know and to do.

b. Determine what the interviewees can actually do so they can be assigned to the right job.

c. Determine the interviewees' deficiencies so that they can be programmed to receive proper training.

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INTERVIEWER'S STANDARDS AND GUIDE for the INDIVIDUAL EQUIPMENT OPERATOR SKILL OF 526 Soil Stabilization

526–Soil Stabilization

CONTENTS

526 Skill Definition

.1 Skill Level 1

.01 Pre-operational services on soil stabilizer mixer.

.02 Operations of soil stabilizer mixer.

.2 Skill Level 2

.01 Perform as grading and compaction foreman.

.02 Set and verify grade stakes and curvature of graded surface.

.03 Interpret the principles and methods of soil stabilization operations.

Figure 1-17.—Title page of the PRCP Interviewer's Standards and Guides.

SKILL DEFINITIONS

Skill Level 1: Individual must make a pre-start check; report or repair discrepancies; perform operator's lubrication; start and check instruments; aerate wet and mix dry and wet materials; maintain specified mixing ratio; utilize system accessories; secure mixer; clean tiller; and maintain operational records and reports.

Applicable Training: 526.1–Soil Stabilization Mixer Operation

Skill Level 2: Skill Level 1 plus direct personnel and control equipment engaged in grading, tamping, rolling, and smoothing areas to specification (surface of airfield, streets, roads); use leveling instruments to set and verify grade stakes and curvature of graded surface; interpret and use the principles and methods of soil stabilization operations.

Applicable Training: 526.2–Soil Stabilization

Skill Level 3: Not applicable.

Figure 1-18.—Individual Rating Skill Definition.

526.1.01 TASK: Pre-Operational Services on Soil Stabilizer Mixer.

Apply these ACTION STATEMENTS to the TASK ELEMENTS listed below:

A. Describe the sequence of steps of this procedure and explain the reasons for each.

B. Describe indications that would be observed during this procedure (lights, breakers, bus-ties, valves, meters, gages, noise, vibration, smoke, etc.).

C. Describe assistance required while performing this procedure.

D. Explain results if this procedure is not performed properly or it is neglected.

E. Discuss safety precautions to be observed.

F. Perform the steps of this procedure when practical.

TASK ELEMENTS:	A	B	C	D	E	F
.01 Conduct visual inspection.	X			X		X
a. Check strike off gates.		X		X		
b. Check tiller blades.		X		X		
.02 Conduct prestart check.	X			X		X
a. Check fluid levels.				X		
.03 Perform daily lubrication.	X			X		X
.04 Perform functional checks.	X	X	X	X	X	X
a. Check water pump.	X			X		

Figure 1-19.—Typical Task Analysis with Task Elements and Related Action Statements.

Next, explain to the interviewees that they should discuss what they know of the skill honestly and that they should not be embarrassed if they don't know every item covered in the guides.

Tell the interviewees what skill and skill level they are being interviewed for. Read the skill definition, as was suggested previously, to see if the interviewees are knowledgeable of the subject.

Task Interviewing

Begin interviewing by reading the task. This helps interviewees to concentrate in the right area. This task should be rephrased: "The first thing we will discuss in soil stabilization is preoperating services on soil stabilizer mixer." Then read the first TASK ELEMENT, (.01 Conduct visual inspection). By applying it through ACTION STATEMENT "A" (Describe the sequence of steps of this procedure and

526.1.02 TASK: Operations of Soil Stabilizer Mixer.

Apply these ACTION STATEMENTS to the TASK ELEMENTS listed below:

A. Describe the sequence of steps of this procedure and explain the reasons for each.

B. List significant tools/equipment/machines used in this procedure.

C. Describe indications that would be observed during this procedure (lights, breakers, bus-ties, valves, meters, gages, noise, vibration, smoke, etc.).

D. Describe assistance required while performing this procedure.

E. Explain results if this procedure is not performed properly or it is neglected.

F. Discuss safety precautions to be observed.

G. Perform the steps of this procedure when practical.

H. Describe types and purpose of forms and records.

TASK ELEMENTS:	A	B	C	D	E	F	G	H
.01 Aerate wet materials.	X				X		X	
a. Check strike off gate position.	X				X			
.02 Dry-mix materials.	X		X		X		X	
a. Maintain depth.					X			
b. Maintain strike off.					X			
.03 Wet-mix materials, utilizing water pump.	X	X	X	X	X		X	
.04 Secure machine.	X				X		X	
a. Clean and repair tiller components.					X	X		
.05 Maintain operators reports and records.								X

Figure 1-20.—Typical Task Analysis with Task Elements and Related Action Statements—Continued.

explain the reasons for each), it would sound something like this:

"Describe the sequence of steps for conducting a visual inspection on the soil stabilizer mixer and explain the reason for each step."

As you can see, this is not a question. It is a statement directing interviewees to tell you what they know about performing the steps of conducting visual inspection and the reasons for performing them. There are no questions in the *PRCP Interviewer's Standards and Guides;* therefore, no answers are provided. The *Guides* point out the areas to be discussed (in terms of task elements and action statements), and the interviewees' replies are evaluated by the interviewer on the basis of personal experience, knowledge, and judgment.

It should be obvious now why all rating skill interviewers MUST be experienced in the skill for which they will interview. The only way you can determine whether or not interviewees know the task element is to thoroughly know it yourself. If you are unfamiliar with, or "rusty" in, any tasks in the *Guides,* study them thoroughly before attempting to interview anyone. Also, if you do not understand how a particular action statement is used with a task element, you must resolve this before interviewing. Discuss the problem with others who are familiar with the skill.

Only discuss the task element with the action statements indicated in the columns to their right by the Matrix. For example, in figure 1-19, only action statements "A", "D", and "F" are used with task elements .01. And, in task element .04, all action statements are applied. As an expert in the skill, you will probably have a desire to "ask questions" in tasks not covered by the *Guides.* This must be avoided as then there will be no standard. If you feel strongly that the *Guides* can be improved, discuss your recommendation with the PRCP coordinator.

Scoring Interviews

If interviewees have an NEC in the skill for which they are being interviewed, they are automatically assigned to that skill level without being interviewed for any of the lower skill levels. Use a positive approach when interviewing. The interviewees either do or do not know the skill. This is left up to your satisfaction as the interviewer. ALL TASKS must be accomplished for each skill level. The results of the interview are then introduced into the PRCP System.

CHAPTER 2

TECHNIQUES OF SUPERVISION

As a first class or chief petty officer, you will no longer concern yourself with just one kind of equipment, that is, automotive or construction. You must become thoroughly familiar with both. Furthermore, you will be expected to do more than perform the duties of lower rated personnel. With advancement, you take on supervisory duties besides. You will be telling others what to do and how to do it. You will need to know how to direct your crews to get the most out of them. You must be able to plan jobs and make estimates, foresee difficulties and devise methods of overcoming them, and set up training programs. You must be safety conscious, making sure your crews work safely at all times.

SUPERVISION

Supervision is probably more of an art than a science; techniques that work well in one situation may not in another. However defined, supervision simply means overseeing and directing the work of others. Although supervision is related to and extends into management, you need not know the distinction between them. Instead, concern yourself with what is generally included in supervision—organizing, delegating, coordinating, checking personnel and equipment, eliminating bottlenecks, and more.

ORGANIZING

As a supervisor, you must be able to organize. In doing so, you study the situation and plan the steps that should bring about desired results. Suppose you are given a crew to handle an earthmoving job in connection with road construction. You should first look at the job to be done and estimate how many man-hours are required to complete it; you will probably have been given a date by which the job is to be completed. Next (or perhaps even before making your estimate of man-hours), plan the sequence of operations. How much clearing and grubbing are required? Is the earth to be merely pushed aside, stockpiled, or hauled away? Are there likely to be drainage problems? Other equipment? What equipment is available, and what is its condition? Is it likely that you will have to request additional equipment for specialized operations? (For instance, cranes attached with an orange peel bucket to move rock.)

You must take careful stock of your crew. Are they experienced in earthmoving operations? Will any training be required before they can operate equipment? Are any of your crewmembers scheduled for leave? Will you need to request additional crewmembers? After getting answers to these questions, you should be able to assign your crewmembers accordingly and set up tentative schedules. If shifts are necessary, make arrangement for the smooth transition from one shift to another with a minimum interruption of work.

DELEGATING

In addition to organizing, you must be able to DELEGATE. Failure to delegate is common among new supervisors. It is natural to want to carry out the details of the job yourself, particularly when you know that you can do better than any of your crewmembers. Trying to do too much, however, is one of the quickest ways to get bogged down in details and slow down a large operation. In an earthmoving operation, you may have as many as 25 crewmembers and a dozen pieces of equipment–scrapers, dozers, front-end loaders, graders, trucks, and the like. Obviously, you cannot be in two places at one time. There will be times when crewmembers need help or instruction in solving problems. If they have to wait until you are available, then valuable time may be lost. It is important, therefore, for you to deputize one or more of them and to delegate authority to make decisions in certain matters. In these cases, you must know who the responsible crewmembers are and who can make sound decisions in your absence.

COORDINATION

The ability to COORDINATE operations is still another important characteristic of a good supervisor. When several operations are in progress, one must dovetail into another to prevent interruption of work flow. An example of coordination is being sure a power shovel has enough dump trucks available to support its production on a continuing basis.

You should make certain that all members of your crew understand their assignments–WHAT they are to do and WHEN they are to do it. In preparing a site for a road, for example, you should see that the scraper operators do not bring their equipment onto the site before the dozer operators have had a chance to clear and strip the area far enough ahead. This gives the scraper operators enough room to operate their equipment in a proper and efficient manner. Failure to coordinate operations can result in some equipment getting in the way of other equipment. You should also be certain that you have assigned the best available piece of equipment to a particular job–dozers for short hauls, scrapers for long hauls, and so on.

CHECKING PERSONNEL AND EQUIPMENT

One of the most important jobs of any supervisor is to keep a constant check upon the personnel and equipment. In carrying out this duty, ask yourself the following questions as you make your inspections.

1. Are plans and specifications being followed?
2. Is the equipment being used efficiently?
3. Are personnel giving their best effort?

You can answer these questions by making a tour of the work sites. When you have many pieces of equipment and a large number of personnel, it may be useful to make a checklist that will help you answer these questions. A checklist on dozer efficiency might contain questions like those shown in table 2-1.

You may need to prepare a checklist for each type of equipment, based on its operational characteristics and recommendations of the manufacturer. It might also be useful to make a checklist for the personnel operating the equipment. Are they reporting on time? Are they skylarking on the job? Are they servicing the equipment properly?

ELIMINATING BOTTLENECKS

Part of your job as a supervisor is to spot causes of delays and eliminate them. Every job has its special problems, and the imagination and ingenuity of the supervisor concerned will determine how a particular problem is solved. Shifting equipment or personnel around, adding equipment (such as a pusher dozer to increase the efficiency of tractor-drawn scrapers), and improving facilities (such as smoothing a haul road or sprinkling to settle dust) are a few examples that may help to eliminate bottlenecks.

JOB CONTROL

The planning of day-to-day job assignments for personnel can be a frustrating job unless you are thoroughly familiar with the capabilities of your crew leaders, crews, and equipment. This is particularly true in a combat zone where the priorities of construction may be subject to change daily. You may have your best crew leader and crew on a road construction

Table 2-1.—Checklist for Dozer Efficiency

LOADS	TRAVEL	SPREADING
1. Are loads heaped?	1. Is optimum speed maintained?	1. Is time being wasted after spread is made?
2. Is the tractor engine up to full rpm, yet working fully?	2. Is backup speed made in as high a gear as possible?	2. Is fill material being spread in layers of proper thickness?
3. Is slot dozing used where possible?	3. Are maximum haul distances less than 300 feet?	
	4. Are downhill dozing and side-by-side dozing used?	

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project, when suddenly an emergency project comes up that requires your crew leader and all or part of the crew, plus a good portion of the equipment, to be dispatched to another jobsite. In that case, you must reorganize and reassign crew leaders and crewmembers so that work on the road can continue.

By knowing your personnel and their capabilities you should be able to control the jobs assigned and the additional ones that arise due to an emergency by:

1. Planning work to utilize manpower.
2. Making sure that each job element is really needed. Eliminate or combine operations when possible.
3. Deciding priority of jobs and having second or third priorities in mind so that personnel and equipment can shift jobs if delayed on a primary project.
4. Insuring that tools, equipment, and spare parts are on hand.
5. Determining types of skills required for different jobs.
6. Determining how many hours a particular job should take under normal or adverse conditions.
7. Conducting inspections while the work is underway and upon completion of the job.

MAINTENANCE OF EQUIPMENT

If maximum production is to be achieved, each piece of equipment must be kept in peak operating condition. Except when shift work is required, each piece of equipment should be assigned to one individual operator. This operator has the responsibility for the daily and weekly preventive maintenance services on the piece of equipment. It is essential that you explain and point out this fact to all operators making sure each one understands. If more than one operator is assigned to a piece of equipment (for example, when you are operating on shifts), you must be sure each operator of that particular piece of equipment for that particular shift is responsible for daily and weekly preventive maintenance. You must also arrange for close liaison with the maintenance supervisor and support personnel who will handle repairs and major maintenance that are beyond the duties of the operator.

INSTILLING MORALE

As defined here, morale concerns the mood or spirit of an individual or a group with respect to performance of duty. High morale is necessary to obtain maximum work output over a period of time.

Don't be mislead into accepting that morale will be high among the operators in a work crew if you allow them to report late, loaf during working hours, use their equipment carelessly, or stop work early. Should you allow them to continue, their morale is bound to suffer and so will job performance.

Fairness in dealing with your crew is necessary to obtain a high level of morale. Individuals must see and understand that everyone is being treated fairly and that some are not being required to do more than their fair share of work.

Personnel are extremely sensitive to partiality by a supervisor. For this reason, you should think ahead about changes, decisions, work assignments, and the like.

In making a decision that only one person is happy with, it seems wise to ask yourself, "How will every other individual in my unit feel about it?"

Good working conditions are also important for a high level of morale. With this in mind, try to make working conditions as comfortable as possible for your crewmembers.

For example, when operating construction equipment in a hot, sunny, humid, dusty area, insure that operators have some type of shading device to shield them from the hot sun. As another example, see that the operators have plenty of drinking water.

Impress upon your crewmembers the importance of their individual assignments and how they fit into the overall project. Competition with other work crews or against a time schedule might be useful in promoting high morale. As a supervisor, try to give your personnel a sense of accomplishment by letting them know that you appreciate hard work and an all-out effort in turning out a good job. Make them proud to be a member of your work crew.

EARNING RESPECT

Respect must be earned. You can't win it by flattery, apple-polishing, throwing your weight around, avoiding issues, or striving for popularity. In supervising your crew, create an atmosphere of courteous and helpful direction. The less noise you make, the better will be the results. There is no room for the "Do as I say, not as I do" approach. In today's technical and ever-changing Navy, the need is for personnel who lead with intelligence, by know-how, and by good example. Good supervision produces a smooth-running organization; poor supervision creates confusion and dissatisfaction.

TRAINING

The training program of each battalion is formulated to provide the personnel with the skills needed to accomplish the battalion's current and mobilization mission. The program is crafted in accordance with the pattern, priorities, and tempo established by the Commanding Officer. The program covers many phases, from orientation courses to special technical courses. It depends upon such factors as operational commitments, policies, and directives from higher authority; experience and previous training of the personnel; and training facilities available. Although much of the construction training will be provided by Class A and C Schools as well as Special SEABEE Training Courses (SCBT), additional skill and experience must be acquired in the battalion.

Training must be closely integrated and coordinated with daily operations of the battalion. The plan and organization for training that is adopted must not interfere with essential construction functions. Nevertheless, the construction schedule should not be so rigid that it overlooks opportunities for training that may expedite construction. Full advantage is taken of the training opportunities that routine operations are likely to present.

Training Needs

Training for advancement concerns all battalion personnel whether at the company or platoon level. As a supervisor, you are responsible for keeping performance records of your operators. Use a Personnel Advancement Requirements (PAR), NAVPERS 1414/4 for keeping these records. It lists, for the next higher rate, every performance factor which an operator has to be tested on. Your operators will need training in factors in which they are found to be unqualified. Since NAVPERS 1414/4 accompanies the service record of personnel being transferred, it will show you what additional training is needed by your new crewmembers.

The battalion's next assignment will also provide clues as to needed training. If the next assignment is to be construction of an airfield, there will undoubtedly be a great deal of earthmoving operations. You will need to see how many qualified operators are available for the various types of construction equipment; you might need to train more crewmembers in the use of scrapers and graders. Or if the next assignment is to require the construction of waterfront facilities, you might have to train several crewmembers in piledriving operations. Your Company Commander, in consultation with the Operations Officer and Training Officer, can give you advice as to training needs based on the battalion's future operations.

A study of the job skills required to do a particular job will be the starting point for training. After you have made this study, take inventory of the skills the members in your crew now possess. You can easily see whether the required skills match the available skills. If they do not match, this is a good indication that some training is needed to bring the crew up to the desired level of proficiency. In some cases, you will need to conduct refresher training; in other cases, you will have to give instructions on new techniques.

As a supervisor, you may also check your crew's service records, conduct personal interviews, and select those best suited for the more formal training given at Class A and C Schools and SCBT.

On-The-Job Training

On-the-job training will probably be your most common training responsibility. Therefore, it is essential that you be equipped to assume the responsibility of training your crew on-the-job.

On-the-job training plays a major role in the development of highly skilled operators. Nothing is a suitable substitute for experience. Since overseas construction is subject to inspection and rigid scheduling, it makes sense to integrate scheduled technical training with on-the-job training. Preferably, the scheduled technical training should be given in field demonstrations of applied construction theory. Training of this type should be aimed at improving individual and crew proficiency and thereby obtain higher quality workmanship. Improved quality will result in improved production since less corrective work will be required.

When the desired level of proficiency has been reached, training should be directed at broadening individual and crew capabilities.

Insofar as practical, you should attempt to rotate your operators on the various jobs involved in normal construction operations so as to provide them the opportunity to broaden their individual capabilities. Training for your senior petty officers should include provisions for becoming familiar with the general aspects of the other construction ratings. (This is cross training.)

Empathy is a much-needed quality in discharging your training responsibility. Good supervisors have the ability to put themselves in the shoes of their operators–to see their needs and to understand their fears and tensions. The ability to empathize will help you recognize the anxiety experienced by new operators, who are in the work area for the first time in new surroundings, and meeting new fellow operators. Empathy will help you see the job from the operator's viewpoint rather than through the eyes of one with years of experience and familiarity with the operation.

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Formal Training

Formal training is, in general, training that goes on outside normal working hours or during periods of enforced nonwork–for instance, inclement weather. Such training usually takes place during regularly scheduled training periods and is often conducted in groups. Participation may or may not be voluntary.

Formal training may also be used when a special operation is scheduled for the battalion, such as a trip to the arctic or the tropics. If the battalion is to get a new type of construction equipment that requires special knowledge for its operation, this too might call for a formal training situation.

There is no "best" method of formal training that applies to every situation, although the lecture-and-demononstration method is most common. Use the method that best fits the training situation. Apply as many good teaching practices as possible. For one, make sure your material is complete. Do not leave out any steps or significant information. Arrange your material in a systematic and orderly manner so that each step rests securely upon the information already provided. Avoid overlapping since too much repetition is a waste of time and usually leads to inattention on the part of the trainees. At the same time, impress upon them the importance of using the correct terminology and/or technical language common to the EO rating. In so doing, your operators should learn more readily and also retain a more detailed picture of the functions and operations of their job.

Subject matter may be classified as knowledge-type, attitude-type, or skill-type.

Knowledge-type subject matter is taught to build up a store of useful facts, principles, theories, and so on. Skill-type subject matter mental or physical is taught for the purpose of helping one acquire the ability to perform a job with ease, speed, and precision. Attitude-type subject matter is taught for the purpose of creating proper feelings, understandings, respect, and the like.

Records and Reports

As an EO1 or EOC, you can expect paperwork to be an important part of your job. For instance, during deployment with a battalion, you will probably be responsible for the preparation of progress reports of construction jobs, as well as inspection and operational reports of equipment utilization. Other paperwork duties may include keeping various logs, charts, graphs, and so on, for your own personal use. See that these and other paperwork duties which could be mentioned are handled carefully and properly. Prior to deloyment with a battalion, long range planning is needed to be certain an ample supply of record and report forms will be on hand. Do not allow yourself to run short during a deployment.

While you may not especially like paperwork, remember that various records and reports are often necessary to make sure a project is completed properly and on time. Make it a practice to keep neat, accurate records and reports; and see that each is submitted by the date due. Have a place to file copies of records and reports; then if you need to obtain information from them, you will know just where to look.

CHAPTER 3

ADVANCED BASE PLANNING, EMBARKATION, AND PROJECT TURNOVER

This chapter discusses principles involving the use of the Naval Planning Facilities Guide which is an advanced base planning document. Guidelines are provided for a system of preparing material and equipment for embarkation. Information also is presented as to how the Equipment Operator will coordinate and supervise the turnover of Alfa Company's projects, material, and equipment.

FACILITIES PLANNING GUIDE

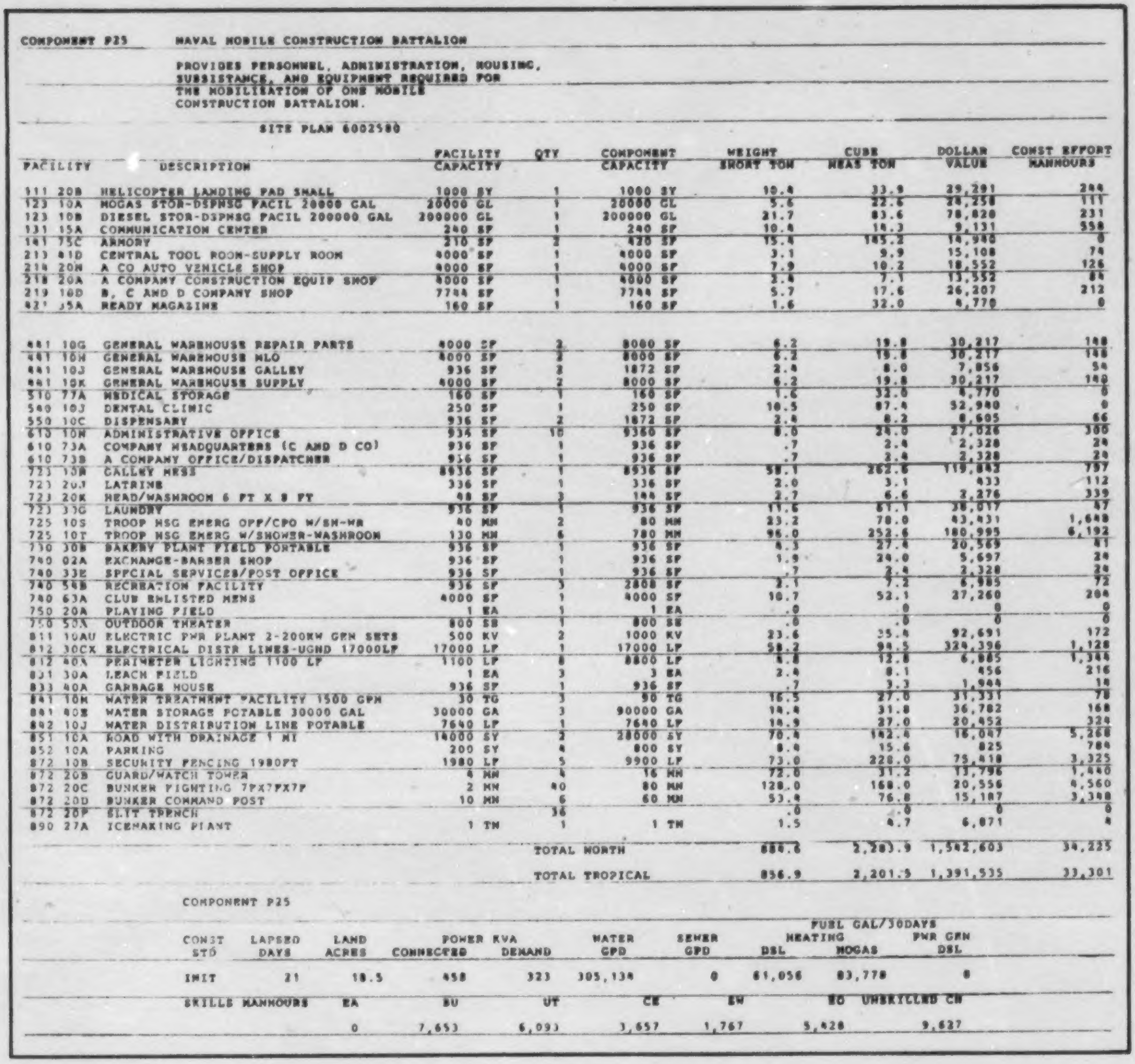
The Naval Planning Facilities Guide (NAVFAC P-437) is the basic document that you should consult when tasked to assist in planning the construction of an advanced base. The Guide consists of two volumes. Volume I contains reproducible drawings of component site plans, facilities, and assemblies. Volume II contains the data for each component, facility, and assembly in the Advanced Base Functional Component (ABFC) System. This volume also contains useful information, such as the crew size, man-hours by skill, land area, and quantities of fuel required to operate a component, facility, or assembly. The Guide offers a choice of alternatives which enable contingency requirements to be met when a complete component is not desired.

There follows three sample pages from the Facilities Planning Guide. See figures 3-1, 3-2, and 3-3. Figure 3-1 provides the personnel, administration, housing, subsistence, and equipment requirements for the P-25 component of a Naval Mobile Construction Battalion. A component consists of the described facilities that are listed by Category Code. Other information provided in particular includes the site plan (identified by a NAVFAC drawing number), capacities, man-hours required by the construction effort, construction standards (that is, initial, intermediate, or temporary), and more.

Now take, for example, the Diesel Storage and Dispensing Facility whose assemblies are listed and described in figure 3-2. Each assembly of this facility is further described in the P-437. Figure 3-3 does this for the Tank Fuel Pillow, the first assembly listed in figure 3-2. Notice that the material requirements for an assembly are listed by National Stock Number (NSN).

The Facilities Planning Guide is your reference for ordering components, facilities, or assemblies. Normally, you should order components only under a mobilization situation with CNO approval. However, facilities and assemblies can be obtained without CNO approval if reimbursement is provided and the project has been approved for a peacetime program. Remember too, facilities and assemblies are not stocked as such, since line items may be common to several facilities or assemblies. Thus, you must allow time for ordering facilities and assemblies, bringing them together at the shipping point, packing them, and shipping them.

Certain installed and collateral equipment, furniture, and fixtures contributed by other system commands or bureaus are NOT furnished with the facilities or assemblies listed in NAVFAC P-437; they must be requested separately. Also remember that, although it may help you in ordering individual items in general supply, NAVFAC P-437 is NOT intended to replace the stock lists of system commands,



COMPONENT P25 NAVAL MOBILE CONSTRUCTION BATTALION

PROVIDES PERSONNEL, ADMINISTRATION, HOUSING, SUBSISTANCE, AND EQUIPMENT REQUIRED FOR THE MOBILIZATION OF ONE MOBILE CONSTRUCTION BATTALION.

SITE PLAN 6002580

FACILITY	DESCRIPTION	FACILITY CAPACITY	QTY	COMPONENT CAPACITY	WEIGHT SHORT TON	CUBE MEAS TON	DOLLAR VALUE	CONST EFFORT MANHOURS
111 20B	HELICOPTER LANDING PAD SMALL	1000 SY	1	1000 SY	10.4	33.9	29,291	244
123 10A	MOGAS STOR-DSPNSG FACIL 20000 GAL	20000 GL	1	20000 GL	5.6	22.6	24,258	111
123 10B	DIESEL STOR-DSPNSG FACIL 200000 GAL	200000 GL	1	200000 GL	21.7	83.6	78,820	231
131 15A	COMMUNICATION CENTER	240 SF	1	240 SF	10.4	14.3	9,131	558
141 75C	ARMORY	210 SF	2	420 SF	15.4	145.2	14,940	0
213 81D	CENTRAL TOOL ROOM-SUPPLY ROOM	4000 SF	1	4000 SF	3.1	9.9	15,108	74
214 20N	A CO AUTO VEHICLE SHOP	4000 SF	1	4000 SF	7.9	10.2	18,552	126
218 20A	A COMPANY CONSTRUCTION EQUIP SHOP	4000 SF	1	4000 SF	3.4	7.1	13,552	84
219 10D	B, C AND D COMPANY SHOP	7744 SF	1	7744 SF	5.7	17.6	26,207	212
421 35A	READY MAGAZINE	160 SF	1	160 SF	1.6	32.0	4,770	0
441 10G	GENERAL WAREHOUSE REPAIR PARTS	4000 SF	2	8000 SF	6.2	19.8	30,217	148
441 10H	GENERAL WAREHOUSE MLO	4000 SF	2	8000 SF	6.2	19.8	30,217	148
441 10J	GENERAL WAREHOUSE GALLEY	936 SF	2	1872 SF	2.4	8.0	7,856	54
441 10K	GENERAL WAREHOUSE SUPPLY	4000 SF	2	8000 SF	6.2	19.8	30,217	148
510 77A	MEDICAL STORAGE	160 SF	1	160 SF	1.6	32.0	4,770	0
540 10J	DENTAL CLINIC	250 SF	1	250 SF	10.5	87.4	52,940	0
550 10C	DISPENSARY	936 SF	2	1872 SF	2.4	8.2	8,605	66
610 10N	ADMINISTRATIVE OFFICE	936 SF	10	9360 SF	8.0	24.0	27,026	300
610 73A	COMPANY HEADQUARTERS (C AND D CO)	936 SF	1	936 SF	.7	2.4	2,328	24
610 73B	A COMPANY OFFICE/DISPATCHER	936 SF	1	936 SF	.7	2.4	2,328	24
723 10N	GALLEY MESS	8936 SF	1	8936 SF	58.1	262.6	119,842	757
723 20J	LATRINE	336 SF	1	336 SF	2.0	3.1	433	112
723 20K	HEAD/WASHROOM 6 FT X 8 FT	48 SF	3	144 SF	2.7	6.6	2,276	339
723 33G	LAUNDRY	936 SF	1	936 SF	11.6	61.1	38,017	47
725 10S	TROOP HSG EMERG OFF/CPO W/SH-WR	40 MN	2	80 MN	23.2	78.0	43,431	1,648
725 10T	TROOP HSG EMERG W/SHOWER-WASHROOM	130 MN	6	780 MN	96.0	252.6	180,995	6,192
730 30B	BAKERY PLANT FIELD PORTABLE	936 SF	1	936 SF	4.3	27.4	20,569	41
740 02A	EXCHANGE-BARBER SHOP	936 SF	1	936 SF	1.9	24.0	5,697	24
740 33E	SPECIAL SERVICES/POST OFFICE	936 SF	1	936 SF	.7	2.4	2,328	24
740 54B	RECREATION FACILITY	936 SF	3	2808 SF	2.1	7.2	6,985	72
740 63A	CLUB ENLISTED MENS	4000 SF	1	4000 SF	10.7	52.1	27,260	204
750 20A	PLAYING FIELD	1 EA	1	1 EA	.0	.0	0	0
750 50A	OUTDOOR THEATER	800 SE	1	800 SE	.0	.0	0	0
811 10AU	ELECTRIC PWR PLANT 2-200KW GEN SETS	500 KV	2	1000 KV	23.6	35.4	92,691	172
812 30CX	ELECTRICAL DISTR LINES-UGND 17000LF	17000 LF	1	17000 LF	58.2	94.5	324,396	1,128
812 40A	PERIMETER LIGHTING 1100 LF	1100 LF	8	8800 LF	4.8	12.8	6,885	1,344
831 30A	LEACH FIELD	1 EA	3	3 EA	2.4	8.1	456	216
833 40A	GARBAGE HOUSE	936 SF	1	936 SF	.7	3.3	1,944	14
841 10M	WATER TREATMENT FACILITY 1500 GPH	30 TG	3	90 TG	16.5	27.0	31,331	78
841 40E	WATER STORAGE POTABLE 30000 GAL	30000 GA	3	90000 GA	14.4	31.8	36,782	168
842 10J	WATER DISTRIBUTION LINE POTABLE	7640 LF	1	7640 LF	14.9	27.0	20,452	324
851 10A	ROAD WITH DRAINAGE 1 MI	14000 SY	2	28000 SY	70.4	142.4	16,047	5,268
852 10A	PARKING	200 SY	4	800 SY	8.4	15.6	825	784
872 10B	SECURITY FENCING 1980FT	1980 LF	5	9900 LF	73.0	228.0	75,418	3,325
872 20B	GUARD/WATCH TOWER	4 MN	4	16 MN	72.0	31.2	13,796	1,440
872 20C	BUNKER FIGHTING 7FX7FX7F	2 MN	40	80 MN	128.0	168.0	20,556	4,560
872 20D	BUNKER COMMAND POST	10 MN	6	60 MN	53.4	76.8	15,187	3,348
872 20F	SLIT TRENCH		36		.0	.0	0	0
890 27A	ICEMAKING PLANT	1 TN	1	1 TN	1.5	4.7	6,871	4
				TOTAL NORTH	884.6	2,283.9	1,542,603	34,225
				TOTAL TROPICAL	856.9	2,201.5	1,391,535	33,301

COMPONENT P25

CONST STD	LAPSED DAYS	LAND ACRES	POWER KVA CONNECTED	POWER KVA DEMAND	WATER GPD	SEWER GPD	FUEL GAL/30DAYS HEATING DSL	FUEL GAL/30DAYS HEATING MOGAS	FUEL GAL/30DAYS PWR GEN DSL
INIT	21	18.5	458	323	305,134	0	61,056	83,778	8

SKILLS MANHOURS	EA	BU	UT	CE	SW	EO	UNSKILLED CN
	0	7,653	6,093	3,657	1,767	5,428	9,627

143.298

Figure 3-1.—Component.

bureaus, offices, single managers, or inventory control points.

EMBARKATION

Any unit of the Naval Construction Force, whether an NMCB, PHIBCB, or CBMU must be ready to deploy or redeploy to complete an assigned mission either by sea, air, or land. To meet the requirements for contingency support of Naval Task and Fleet Marine Forces, a minimum of two-thirds of the Naval Construction Force must be capable of redeployment within 10 day. After 60 days in

FACILITY 123 10B JCS PLANNING FACTOR

DIESEL STORAGE AND DISPENSING FACILITY
200000 GALLON

THIS FACILITY PROVIDES 200000 GALLON OF DIESEL OIL STORAGE AND RECEIVING-DISPENSING CAPABILITY.

NAVFAC DRAWING NUMBER 6002621

ASSEMBLY	DESCRIPTION	ZONE	QTY.	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE	CONST EFFORT MANHOURS
20002	TANK FUEL PILLOW 50000 GAL		4	7,610.8	644.4	20,805.76	112
20124	HOSE MANF F/200000 GAL TANK ARR		1	564.2	60.4	1,491.61	2
20204	FUEL TRANSFER ASSEMBLY 350 GPM		1	3,945.9	447.5	7,872.64	44
20305	FUEL DISPENSING ASSY PORTABLE		1	1,615.9	52.9	2,519.74	8
20506	FUEL FILTER AND METER ASSY 600 GPM		1	3,329.4	276.1	8,625.71	22
20508	HEATER FUEL HOT OIL 350 GPM	N	1	25,092.5	1,751.9	36,859.07	24
20703	TANK FUEL 275 GAL W/PIPING		2	758.2	91.9	319.84	16
29702	EXTINGUISHER FIRE W/BRKT PKP 20 LB		3	540.0	18.9	325.14	3

	SHORT TON	MEAS TON	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE	CONST EFFORT MANHOURS
TOTAL NORTH	21.7	83.6	43,456.9	3,344.0	78,819.51	231
TOTAL TROPICAL	9.2	39.8	18,364.4	1,592.1	41,960.44	207

FACILITY 123 10B PRIMARY 200,000 GL SECONDARY 0

CONST STD	LAPSED DAYS	LAND ACRES	POWER KVA CONNECTED	POWER KVA DEMAND	VOLTS	PHASE	WATER TOT. GPD	WATER PEAK GPM	SEWER GPD	RECOV. CODE
INIT	0	1.28	17	8	208	3	0	0	0	

FUEL (GAL/30DAYS) HEATING DSL	HEATING MOGAS	PWR GEN DSL	SKILLS MANHOURS EA	BU	UT	CE	SW	EO	UNSKILLED CN
0	490	0	0	0	119	0	0	88	24

143.299

Figure 3-2.—Facility.

ASSEMBLY 20002

TANK FUEL PILLOW 50000 GAL

THIS ASSEMBLY PROVIDES 50000 GALLON OF FUEL STORAGE.

NAVFAC DRAWING NUMBER 6002614

COG	STOCK NUMBER	DESCRIPTION	UI	QTY	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE
9C	4710-00-639-9445	PIPE STL BLK 2	FT	20	75.00	.7800	9.80
9C	4710-00-273-1641	PIPE CULVT NEST 12N ALUM	EA	4	26.40	2.1600	21.52
9C	4720-00-978-8867	HOSE ASSY RBR 4X10 SUCT	EA	3	171.00	7.5000	246.00
9C	4730-00-[illegible]-9286	COUPLING MLF QCPLR 4FX4F	EA	2	16.00	.4000	34.80
9C	4730-00-196-2079	NIPPLE PP SHRT 4X4	EA	1	3.15	.0600	1.20
9C	4820-00-289-2674	VALVE GATE QUICK 2NPT	EA	1	11.00	.2000	27.70
9Z	5330-00-899-4509	WASHER RBR 4 HSE CPLG	EA	3	.15	.0030	.42
2C	5430-00-999-3739	TANK FAB COL 50000GL	EA	1	1,600.00	150.0000	4,860.00
	ASSEMBLY 20002			TOTAL	1,902.70	161.1030	5,201.44

FUEL (GAL/30DAYS) HEATING DSL	HEATING MOGAS	PWR GEN DSL	SKILLS MANHOURS EA	BU	UT	CE	SW	EO	UNSKILLED CN	CONST EFFORT MANHOURS
0	0	0	0	0	2	0	0	22	4	28

NOTE - CREW SIZE: 1 EO, 1 UT, 2 CN

143.300

Figure 3-3.—Assembly.

their homeport, Naval Construction Force Units should be capable of redeployment within 10 days. While en route to or from deployment sites, units must be prepared for immediate diversion to emergency, contingency, or mobilization assignments. Constant attention, meticulous pre-planning, and frequent exercise are therefore essential to maintain the embarkation readiness required to carry out these assignments.

For an effective embarkation, liaison between the battalion embarkation staff and Alfa company must be established. If designated by the Alfa Company Commander to act as the embarkation representative, you keep the battalion team embarkation offices informed of Alfa Company's shipping requirements and insure that mount-out box construction, color coding, and numbering are in accordance with directives; that each box, pallet, or skid required for mount-out is available; that packing lists are current and accurate; that covers and hardware to attach them to their respective boxes are available; that company cargo manifests and vehicle tables are maintained, reviewed, and forwarded to the embarkation offices.

During an amphibious embarkation, Alfa Company personnel operates equipment as follows: warehouse or rough terrain forklifts needed at the base camp, staging area, pier side, or boat basin; lowboy trucks to move tracked equipment that cannot readily travel over highways; semi-flatbed trucks to move all palletized cargo or, in some cases, loose boxes; semi-vans to move seabags and any troop space gear that will be hand-carried aboard ship; buses to haul the troops that form the advance party, main body, or rear echelon so each group will arrive at pier side or boat basin when the loading of vehicles and cargo is completed; and wreckers needed at the staging area and those traveling with each convoy that departs the base camp.

In addition to the above, Alfa Company personnel will be moving the vehicles, equipment, and cargo that are scheduled to be embarked to the staging area.

The movement of personnel, supplies, and equipment by fixed wing aircraft or helicopter involves basically the same planning and embarkation procedures as for amphibious loadouts. However, Alfa Company has some specific planning responsibilities in an air embarkation that it doesn't have in an amphibious embarkation.

To assist the loadmaster in the actual loading of aircraft, all vehicles and rolling stock must be plainly marked to show the vehicle's gross weight and center of gravity. Remember, the gross weight includes all cargo that may be preloaded in the vehicle. An empty vehicle does not have the same center of balance it has when preloaded with cargo. Be sure that the correct vehicle weight is marked at the center of balance and axle weights are placed over the wheels.

Fuel tanks will be drained on all non-self-propelled vehicles, the cap to the fuel tank secured, and the air vent taped over prior to being staged for loading aboard the aircraft.

All self-propelled vehicle fuel tanks are usually at a 3/4 full capacity but never less than 1/4 full. This is also true of auxiliary fuel tanks or extra fuel cans being carried.

All cargo or stake side rails should be securely lashed to the trucks or trailers prior to loading.

Both winch and pintle hook equipped vehicles must be available to assist in loading and offloading.

Insure all vehicles and equipment have been checked and serviced prior to departure.

Insure all collateral equipment and pre-cut shoring accompany the vehicles and equipment.

Move the vehicles, equipment, and cargo scheduled for the air detachment movement to the airport and load as directed.

There may be a need for an NMCB or another unit of the Naval Construction Force to move all or part of their P-Component allowance by road convoy to a new site in conjuction with operational commitments. The road convoy may be required in combination with an initial or final move by air or sea. After such an order has been given, Alfa Company's responsibilities are to provide transportation and equipment support in a logical and orderly manner to the selected site.

To support a road convoy, Alfa Company will furnish experienced personnel to serve as Convoy Commander, Pace Setter, and Trail Maintenance Officer. The Convoy Commander (usually the assistant Alfa Company Commander) is responsible for the convoy action during movement, initiates the march, issues and enforces march orders, and supervises the movement. The Pace Setter is an experienced Equipment Operator who drives the lead vehicle and maintains speed as set forth by the Convoy Commander. The Trail Maintenance Officer (MCPO/SCPO/CPO) makes sure before convoy movement that the necessary equipment and gear is stowed on the vehicles in order to take care of convoy vehicle maintenance. The Trail Maintenance Officer makes sure at halts, that all convoy vehicles are checked by their drivers and that the maintenance crew makes necessary repairs.

The Alfa Company Commander has logistic responsibility for the road convoy covering all areas of operation, such as fuel, water, rations, spare parts, equipment, weapons, and ammunition. For example, the Commander insures that the fuel supply will be sufficient for 15 days plus a 5-day reserve, that each vehicle carries one 5-gallon can of potable water, that rations are sufficent for 15 days plus a 5-day reserve, that individual and crew serve weapons are carried, and that the supply of ammunition will last 20 days plus a 5-day reserve.

PROJECT TURNOVER

About 30 days before an NMCB completes its deployment, the advance party of the relieving battalion is sent to the deployment site to make all arrangements for the arrival of the main body of the battalion. This is done in order to accomplish successfully a battalion turnover of projects, material, and equipment. The on-site proceedings consist of taking inventory of the camp, supply, material, and equipment.

Camp, supply, and material inventories are conducted by members of both battalions to determine deficiences or surpluses in requirements. They inventory items, such as administrative and operational machines and consumables; weapons and infantry equipment, toolkits and toolroom supplies; special clothing and bedding; NBC defensive devices; equipment and materials for communications, medical and dental services, damage control and safety, photography and barber supplies; camp facility collateral equipment and supplies; galley and messing equipment; provisions; and camp support-related equipment.

The equipment inventory, better known as the Battalion Equipment Evaluation Program (BEEP), is conducted by assigned personnel of Alfa Company representing both battalions. It provides a continued uniform procedure for the evaluation and accountability of all equipment, attachments, collateral equipage, maintenance records, and correspondence. When assigned, but before participating, familiarize yourself with the current COMCBPAC/COMCBLANT Instructions, 11200.1 series. These instructions are established as uniform procedures which must be performed during a battalion's on-site relief and equipment turnover.

The following tasks are accomplished jointly by battalion personnel:

1. Insure that a copy of the Equipment Evaluation Inspection Guide (figure 3-4), along with a copy of the Attachment Evaluation Inspection Guide (figure 3-5), when needed, is prepared for each item of equipment.

NOTE: The Equipment Condition Codes as defined below are used in completing the parts of figures 3-4 and 3-5 that describe the overall condition of the equipment.

ALPHABETICAL CODING

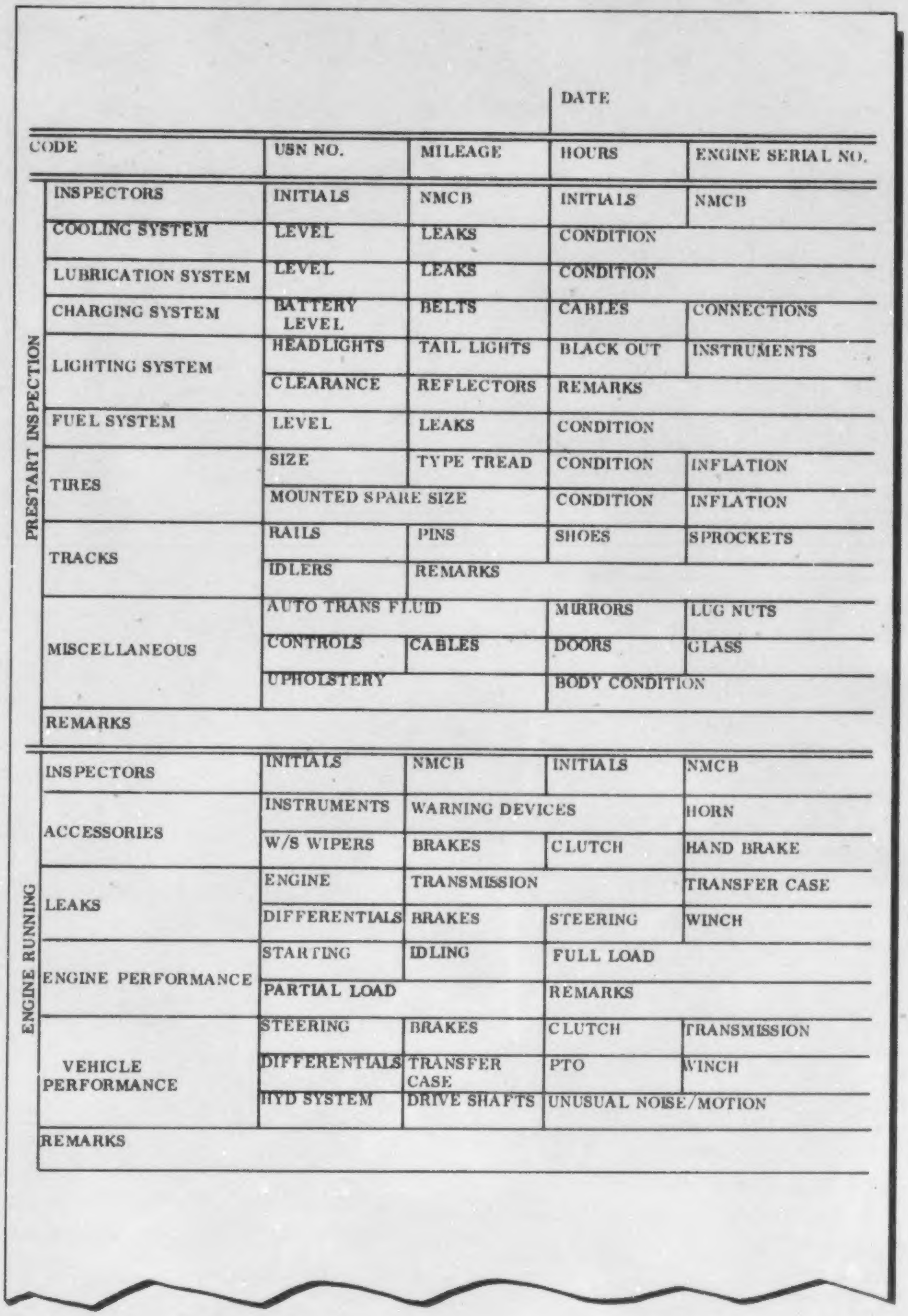
N–New, unused.

E–Used, but reconditioned (overhauled); Not used since overhaul.

O–Used; fully operational, without repairs.

R–Deadlined; repairs required before this item can perform its intended mission.

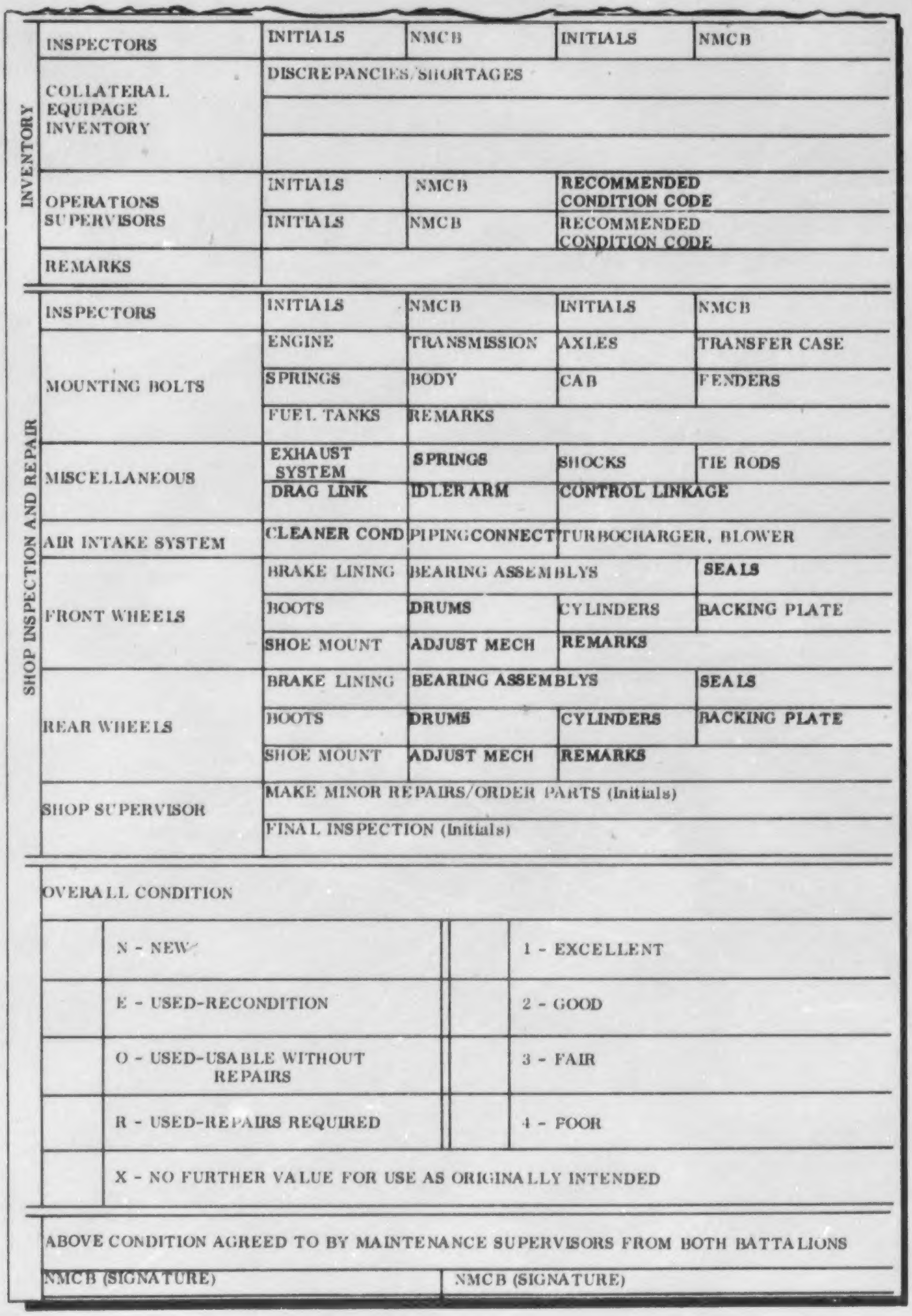
X–No further value for use as orginally intended.



				DATE	
CODE		USN NO.	MILEAGE	HOURS	ENGINE SERIAL NO.
PRESTART INSPECTION	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
	COOLING SYSTEM	LEVEL	LEAKS	CONDITION	
	LUBRICATION SYSTEM	LEVEL	LEAKS	CONDITION	
	CHARGING SYSTEM	BATTERY LEVEL	BELTS	CABLES	CONNECTIONS
	LIGHTING SYSTEM	HEADLIGHTS	TAIL LIGHTS	BLACK OUT	INSTRUMENTS
		CLEARANCE	REFLECTORS	REMARKS	
	FUEL SYSTEM	LEVEL	LEAKS	CONDITION	
	TIRES	SIZE	TYPE TREAD	CONDITION	INFLATION
		MOUNTED SPARE SIZE		CONDITION	INFLATION
	TRACKS	RAILS	PINS	SHOES	SPROCKETS
		IDLERS	REMARKS		
	MISCELLANEOUS	AUTO TRANS FLUID		MIRRORS	LUG NUTS
		CONTROLS	CABLES	DOORS	GLASS
		UPHOLSTERY		BODY CONDITION	
	REMARKS				
ENGINE RUNNING	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
	ACCESSORIES	INSTRUMENTS	WARNING DEVICES		HORN
		W/S WIPERS	BRAKES	CLUTCH	HAND BRAKE
	LEAKS	ENGINE	TRANSMISSION		TRANSFER CASE
		DIFFERENTIALS	BRAKES	STEERING	WINCH
	ENGINE PERFORMANCE	STARTING	IDLING	FULL LOAD	
		PARTIAL LOAD		REMARKS	
	VEHICLE PERFORMANCE	STEERING	BRAKES	CLUTCH	TRANSMISSION
		DIFFERENTIALS	TRANSFER CASE	PTO	WINCH
		HYD SYSTEM	DRIVE SHAFTS	UNUSUAL NOISE/MOTION	
	REMARKS				

2.473

Figure 3-4.—Equipment Evaluation Inspection Guide.



INVENTORY	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
	COLLATERAL EQUIPAGE INVENTORY	DISCREPANCIES/SHORTAGES			
	OPERATIONS SUPERVISORS	INITIALS	NMCB	RECOMMENDED CONDITION CODE	
		INITIALS	NMCB	RECOMMENDED CONDITION CODE	
	REMARKS				
SHOP INSPECTION AND REPAIR	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
	MOUNTING BOLTS	ENGINE	TRANSMISSION	AXLES	TRANSFER CASE
		SPRINGS	BODY	CAB	FENDERS
		FUEL TANKS	REMARKS		
	MISCELLANEOUS	EXHAUST SYSTEM	SPRINGS	SHOCKS	TIE RODS
		DRAG LINK	IDLER ARM	CONTROL LINKAGE	
	AIR INTAKE SYSTEM	CLEANER COND	PIPINGCONNECT	TURBOCHARGER, BLOWER	
	FRONT WHEELS	BRAKE LINING	BEARING ASSEMBLYS		SEALS
		BOOTS	DRUMS	CYLINDERS	BACKING PLATE
		SHOE MOUNT	ADJUST MECH	REMARKS	
	REAR WHEELS	BRAKE LINING	BEARING ASSEMBLYS		SEALS
		BOOTS	DRUMS	CYLINDERS	BACKING PLATE
		SHOE MOUNT	ADJUST MECH	REMARKS	
	SHOP SUPERVISOR	MAKE MINOR REPAIRS/ORDER PARTS (Initials)			
		FINAL INSPECTION (Initials)			

OVERALL CONDITION

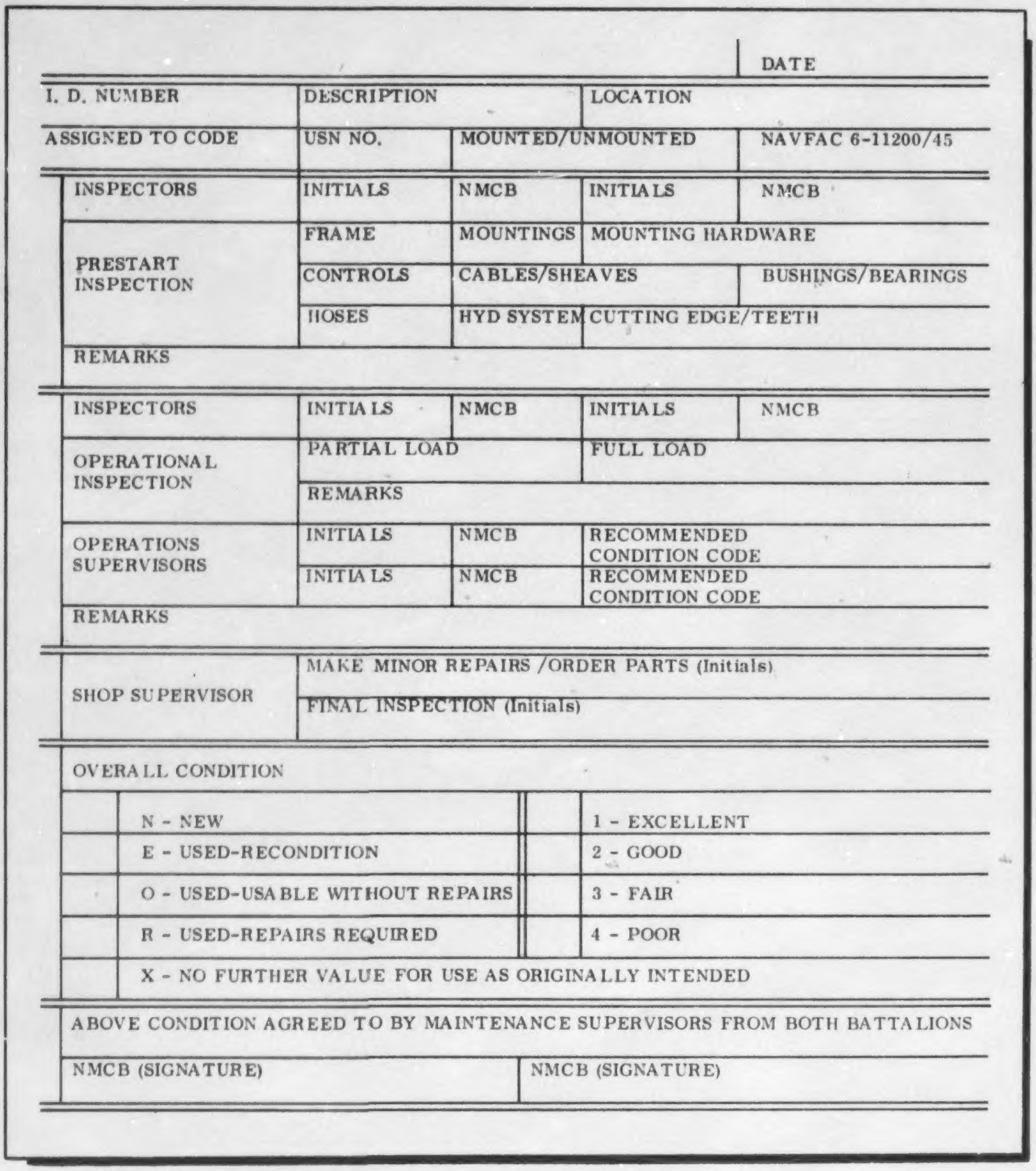
	N - NEW		1 - EXCELLENT
	E - USED-RECONDITION		2 - GOOD
	O - USED-USABLE WITHOUT REPAIRS		3 - FAIR
	R - USED-REPAIRS REQUIRED		4 - POOR
	X - NO FURTHER VALUE FOR USE AS ORIGINALLY INTENDED		

ABOVE CONDITION AGREED TO BY MAINTENANCE SUPERVISORS FROM BOTH BATTALIONS

NMCB (SIGNATURE)	NMCB (SIGNATURE)

2.473

Figure 3-4.—Equipment Evaluation Inspection Guide—Continued.



				DATE
I. D. NUMBER	DESCRIPTION		LOCATION	
ASSIGNED TO CODE	USN NO.	MOUNTED/UNMOUNTED		NAVFAC 6-11200/45
INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
PRESTART INSPECTION	FRAME	MOUNTINGS	MOUNTING HARDWARE	
	CONTROLS	CABLES/SHEAVES		BUSHINGS/BEARINGS
	HOSES	HYD SYSTEM	CUTTING EDGE/TEETH	
REMARKS				
INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
OPERATIONAL INSPECTION	PARTIAL LOAD		FULL LOAD	
	REMARKS			
OPERATIONS SUPERVISORS	INITIALS	NMCB	RECOMMENDED CONDITION CODE	
	INITIALS	NMCB	RECOMMENDED CONDITION CODE	
REMARKS				
SHOP SUPERVISOR	MAKE MINOR REPAIRS /ORDER PARTS (Initials)			
	FINAL INSPECTION (Initials)			

OVERALL CONDITION

	N - NEW		1 - EXCELLENT
	E - USED-RECONDITION		2 - GOOD
	O - USED-USABLE WITHOUT REPAIRS		3 - FAIR
	R - USED-REPAIRS REQUIRED		4 - POOR
	X - NO FURTHER VALUE FOR USE AS ORIGINALLY INTENDED		

ABOVE CONDITION AGREED TO BY MAINTENANCE SUPERVISORS FROM BOTH BATTALIONS

NMCB (SIGNATURE)	NMCB (SIGNATURE)

2.474

Figure 3-5.—Attachment Evaluation Inspection Guide.

NUMERICAL CODING

1–Excellent Condition (repairs would cost no more than 10% of acquisition cost to upgrade condition to E-1.)

2–Good Condition. Does not qualify for excellent; slightly shop worn, but with considerable use left before any important repairs would be required. (Repairs would cost from 11% to 25% of acquisition cost to upgrade to E-1.)

3–Fair Condition. Worn, rusted, or deteriorated to the extent where some parts or portions should be replaced. (Repairs would cost from 26% to 40% to upgrade to E-1.)

4–Poor Condition. Badly worn, rusted, deteriorated and would still be in doubtful state of dependability and uneconomical in use, if repaired at location. (Repairs would cost from 41% to 65% of acquisition cost to upgrade to E-1.)

NOTE: Repair costs by percentage of acquisition as set forth in numerical coding will only pertain to deadline equipment only.

2. Inspect all maintenance records, noting accuracy and deficiences and updating as required.

3. Review and account for all maintenance correspondence that is pending final action.

4. Inventory and inspect all permanent Alfa Company shop equipment, noting condition and deficiences. Submit a list to the COMCBLANT or COMCBPAC Equipment Office representative.

5. Conduct a preventive maintenance inspection of each nonpreserved item of USN-numbered equipment assigned, using the Equipment Evaluation Inspection Guide. Accomplish all repairs possible dependent upon the work force, space, and repair parts available as determined jointly by both maintenance supervisors.

6. Utilize repair parts in accordance with COMCBLANT/COMCBPAC Instruction 4040.1 series.

There are various documents and supplies that provide a ready reference for members participating in the on-site proceedings. Those that you will need are pertinent COMCBPAC/COMCBLANT Instructions, Equipment Officer's Technical Bulletins, Equipment Officer's Modification Work Orders, NMCB Table of Allowance, and sufficient NMCB decals (red diamond-shaped for organic equipment and white diamond-shaped for augment allowance equipment).

You will work with the relieving battalion's personnel during on-site proceedings and will be assisted by BEEP representatives from COMCBPAC/COMCBLANT Staff or COMCBPAC/COMCBLANT Equipment Office. Their duties include (1) on-site indoctrination, (2) providing technical assistance required, (3) holding a comprehensive inspection of the relieved battalion to determine the overall effectiveness of the relieved battalion's equipment management program, (4) conducting a random inventory of repair parts stock to determine the accuracy of the existing inventory, (5) conducting a critique upon completion of the BEEP, and (6) preparing and submitting a BEEP completion report (figure 3-6) to COMCBPAC or COMCBLANT with copies to appropriate information addressees.

NARRATIVE REPORT OF THE BEEP BETWEEN NMCB AND NMCB

1. The COMCBLANT/COMCBPAC Equipment Office Representative(s), ______________ arrived at NMCB__________ at Camp________________ at ________________ on______________ for the purpose of observing the BEEP between NMCB________________ and NMCB________________.

2. A BEEP indoctrination briefing was presented at ________________ on ________________ to appropriate personnel.

3. The BEEP commenced at________ on ________ and was completed at________ on________. Items of equipment located at ____________________ were not evaluated and are so indicated on enclosure ______________________________ ___

a. Significant events of the BEEP were discussed at the Post-BEEP critique at ________ on ________________. The following personnel were present:

____
____
____
____
____
____

____
____
____
COMCBLANT Equipment Office Representative

COMCBPAC Equipment Office Representative

b. A Post-BEEP briefing was conducted for the following personnel (appropriate Equipment Office).

NAME	TITLE	COMMAND

4. The condition of the Organic Allowance Equipment is as follows:

a. Excellent – __________________ item– ________________________________ percent

b. Good – __________________ item– ________________________________ percent

c. Fair – __________________ item– ________________________________ percent

d. Poor – __________________ item– ________________________________ percent

e. ________________ percent of the equipment in the fair and poor categories is presently scheduled for replacement.

Figure 3-6.–Outline of narrative report of Battalion Equipment Evaluation Program.

5. The condition of the Augment Equipment is as follows:

a. Excellent – ____________ item– ____________ percent

b. Good – ____________ item– ____________ percent

c. Fair – ____________ item– ____________ percent

d. Poor – ____________ item– ____________ percent

e. The following attachment shortage were noted:

____________ ____________

____________ ____________

____________ ____________

6. Equipment correspondence files were reviewed for turnover to NMCB____________.

7. Equipment management and cost control records were reviewed. History jackets were purified. The following information has been compiled from NMCB____________ P.M. records for the period________ through________.

a. P.M.'s to interim repairs was________to________.

8. Collateral equipage was inventoried and the total monetary value of shortages was:

From	No. of Items	Total Cost
a. Wreckers	________	________
b. Bridge and dock component	________	________
c. Rock drills	________	________
d. Earth augers	________	________
e. Lube skids	________	________
f. Woodworking shops	________	________
g. Machine shops	________	________
h. Fire truck	________	________
i. Collateral equipage	________	________
TOTAL	________	________

j. Funds were requested/received from COMCBPAC/COMCBLANT and the items have/have not been placed on order.

9. Deadline.

a. There were_____ items (_____percent) on deadline at the commencement of the BEEP.

b. There were_____ items (_____percent) on deadline at the conclusion of the BEEP.

10. General Comments/Commendatory Items:

Figure 3-6.–Outline of narrative report of Battalion Equipment Evaluation Program–Continued.

CHAPTER 4

CONSTRUCTION SCHEDULING

In construction work, schedules play an important part in keeping production flowing evenly and getting a project done on time. This chapter explains some of the basic factors of scheduling the sequence of projects on a deployment or the sequence of operations on a project. Topics covered include types of schedules, techniques of scheduling, and methods of progress control.

From experience, you may have already learned that network analysis is a valuable management tool in planning, scheduling, and controlling construction operations. Special attention is given to the NETWORK ANALYSIS METHOD of scheduling. Fundamentals of network analysis and the method of constructing a network analysis diagram are explained. At appropriate places, you are given definitions of terms used in connection with network analysis.

USES OF A CONSTRUCTION SCHEDULE

Before, during, and after construction, the schedule serves as an operational guide for all managerial and supervisory personnel. Without the schedule, coordination and teamwork would be difficult to achieve.

BEFORE CONSTRUCTION

Before work actually begins, the schedule insures that the person in charge has an idea of the time required for construction. It shows clearly the sequence in which personnel, materials, and equipment are required, thus allowing one job to be intergrated with another, and insuring maximum utilization of the constructing unit's capability.

DURING CONSTRUCTION

During construction, the schedule serves as a basis upon which to issue orders to subordinates. It insures that equipment is not tied up longer than necessary, and that large numbers of personnel are not brought on the job before they can be employed efficiently. Such a situation is not only wasteful, but is quickly interpreted as lack of organization, and will have an extremely adverse effect on morale. The schedule enables the supervisor to prepare checklists to see exactly what jobs should be in operation at a given time, rather than to assume "everyone is working, so everything must be all right." The schedule is a means of insuring that material is not produced or delivered long before it is required, that storage facilities are utilized efficiently, and that effort is not expended needlessly in rehandling materials.

When field changes occur or production is slowed, the schedule serves as a basis by which a supervisor can evaluate the effects upon related work items and devise solutions which will cope with the changes in scheduled operations.

Up-to-date actual progress, plotted upon the schedule at regular and frequent intervals, reveals work items that are falling behind schedule in time to apply corrective action. The schedule also serves as the basis for preparation of progress reports to higher command levels.

AFTER CONSTRUCTION

After the project is completed, an analysis of the schedule can be useful in isolating information for future reference. Noting which items fell behind or were completed ahead of schedule will enable estimators to reevaluate their time rates and modify them for future use based on new experience.

ELEMENTS OF SCHEDULING

The elements used in scheduling work include the work item number, the item description, the unit of measurement (cu yd, sq yd, ton, each, etc), the quantity of work to be performed, the relation of each item to the whole in terms of work to be performed (such as percentage of the total work required for each item), units of time to be used in the schedule, the starting date, the time required for each item, and the completion date. The elements of scheduling equipment and manpower are similar to those of scheduling work, but in addition include the number of pieces of equipment and number of personnel.

PRINCIPLES OF SCHEDULING

The development of a schedule is governed by four principles which remain fixed even though the type of schedule is changed.

SCHEDULED OPERATIONS CANNOT EXCEED THE CAPABILITY TO ACCOMPLISH THE WORK. For example, if only five bulldozers are available, the maximum possible which can be scheduled at any given time is five.

SCHEDULED OPERATIONS MUST FOLLOW THE SEQUENCE OF WORK REQUIRED FOR THE PARTICULAR JOB. For instance, the same part of a road cannot be surfaced while the base course is being constructed, nor can a roof be put on a building before the foundation and walls are up.

These two principles may appear so obvious as to merit little attention, yet the most common errors in scheduling involve violations of both. If a schedule is made which does not violate either of these principles it will be a workable schedule, but it will not necessarily be a good schedule. Two other principles must be observed to develop a good schedule.

CRITICAL ITEMS MUST BE SCHEDULED AS SOON AS POSSIBLE. Maximum speed of completion of a project is most frequently the aim in advanced base construction. This is usually achieved by scheduling those items which take longest, or upon which many other operations are based, to begin as early as possible.

SCHEDULING MUST INSURE CONTINUITY OF WORK EFFORT. Maximum efficiency in accomplishing a particular work item is best achieved if the time for accomplishing that item is as continuous as possible. For example, a grader on a road job should not be required to change, during short periods, from fine grading to sloping ditches to some other type of work. This reduces the output, and requires more supervisory personnel. These last two principles are often in opposition to one another and a balance must be made between them to obtain the best schedule.

TYPES OF SCHEDULES

Work schedules are usually prepared for the deployment as a whole and for each project of the deployment. Manpower and equipment schedules are normally prepared at the same time, because the information they contain is required for preparation of the work schedules. The separate projects of a deployment are scheduled in the deployment schedule; the separate work elements of a project are scheduled in a project schedule.

A typical deployment work schedule is shown in figure 4-1. The deployment will accomplish three projects; (1) the construction of 22 replacement housing units, (2) the laying of 12,600 linear feet of a POL (petroleum, oil, and lubricant) system, and (3) the construction of 28,000 sq yd of road. It is estimated that, of the total work time allotted, 58.7 percent will be required for the replacement housing, 23.9 percent for the POL system, and 17.4 percent for the roads.

Project 1 will begin in March and end in October; project 2 will begin in April and end in October; and project 3 will begin in March and end in July. The estimated percentage of completion of each project for each month is as

DEPLOYMENT WORK SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 19- PREPARED 1-4- BY G. SMITH

PROJECT NO.	DESCRIPTION	UNIT	QUANTITY	WEIGHTED VALUE [1]	MONTHLY PRODUCTION – EST. AND ACT.							
					MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
1	REPLACEMENT HOUSING	UNITS	22	58.7	10	25	34	43	52	66	85	100
2	POL SYSTEM	LF	12,600	23.9		2	18	39	58	80	91	100
3	ROADS	SY	28,000	17.4	8	31	58	75	100			
	TOTAL PROJECT			100.0	7	21	34	48	62	76	89	100

[1] WEIGHTED VALUE IS THE PERCENTAGE OF THE TOTAL MAN-DAYS ALLOCATED TO EACH PROJECT.

82.91

Figure 4-1.–Deployment work schedule.

shown. These monthly figures are used to determine the estimated percentage of completion of the total project (deployment) shown at the bottom of the page. For example: in May, 34 percent of 58.7 percent, 18 percent of 23.9 percent, and 58 percent of 17.4 percent of the work will be accomplished. This amounts to 34 percent of the total work.

Figure 4-2 shows the work schedule for one of the projects shown figure 4-1. Figure 4-3 shows the deployment manpower schedule for 1 month of deployment. The total man-days per month figure at the bottom is the sum of the total per day full-day figures, plus half the sum total per day half-day figures. Figure 4-4 shows a one-month manpower schedule for one of the projects shown in figure 4-3.

Figure 4-5 shows the equipment schedule for the deployment. The interval during which each item of equipment will be required is indicated by a BAR at the right. In figure 4-6, a similar chart (called a BAR CHART) shows the 1-month equipment schedule for one of the projects. Figure 4-7 shows a simple tabular type of project work schedule.

TECHNIQUES OF SCHEDULING

In scheduling a project, the first procedure is to list the work elements. Next, determine the construction sequences; obviously, excavating must come before foundation placement, building completion before base course and paving materials can be placed, etc. The starting date for the project is, of course, the starting date for the work element which is first in construction sequence.

The time required for each work element is determined by dividing the estimated man-days required by the number of persons expected to be assigned to constructing that element. Each work element is scheduled in its proper construction sequence, showing starting and

PROJECT WORK SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 19– PREPARED 1-4– BY G. SMITH
PROJECT -- POL SYSTEM

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	WEIGHTED VALUE	MONTHLY PRODUCTION – EST. AND ACT.							
					MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
2A11	TRENCHING, DITCHING, & BACKFILLING	CY	2,200	9.1		10	27	44	61	78	95	100
2M2	INSTALL VALVES	EACH	25	0.9					15	50	80	100
2M4	CONSTRUCTION VALVE PITS	EACH	10	10.9			10	40	65	90	100	
2M13	INSTALL 12" PIPE	LF	12,600	58.2			20	39	58	77	95	100
2R9	PUMP HOUSE	EACH	1	15.4			15	40	65	85	100	
2Q3	WORK NOT COVERED ABOVE	L/S	1	5.5		5	20	40	55	70	90	100
	TOTAL PROJECT			100.0		1	18	39	60	79	96	100

Figure 4-2.—Project work schedule. 82.92

DEPLOYMENT MANPOWER SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 19– PREPARED 1-4– BY G. SMITH
PROJECT -- POL SYSTEM

PR. NO.	DESCRIPTION	DATE	JULY																														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	REPLACEMENT HOUSING	E	47	47	49	☒	⧄ 49	☒	49	41	48	48	48	⧄ 50	☒	46	54	54	50	54	⧄ 54	☒	54	47	47	43	50	⧄ 47	☒	47	47	42	42
		A																															
2	POL SYSTEM	E	50	50	48	☒	⧄ 48	☒	48	56	49	49	49	⧄ 47	☒	51	43	43	47	43	⧄ 43	☒	43	50	50	54	47	⧄ 50	☒	50	50	55	55
		A																															
3	ROADS	E	40	40	40	☒	⧄ 40	☒	40	40	40	40	40	⧄ 40	☒	40	40	40	40	40	⧄ 40	☒	40	40	40	40	40	⧄ 40	☒	40	40	40	40
		A																															
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		A																															
		E																															
		A																															
		E																															
		A																															
TOTAL PERSONS PER DAY		E	137	137	137	☒	⧄ 137	☒	137	137	137	137	137	⧄ 137	☒	137	137	137	137	137	⧄ 137	☒	137	137	137	137	137	⧄ 137	☒	137	137	137	137
		A																															
TOTAL MAN-DAYS PER MONTH		E	3288																														
		A																															

☒ DENOTES SUNDAYS AND HOLIDAYS WHEN NO WORK IS SCHEDULED.

⧄ DENOTES SATURDAYS WHEN HALF DAY'S WORK IS SCHEDULED.

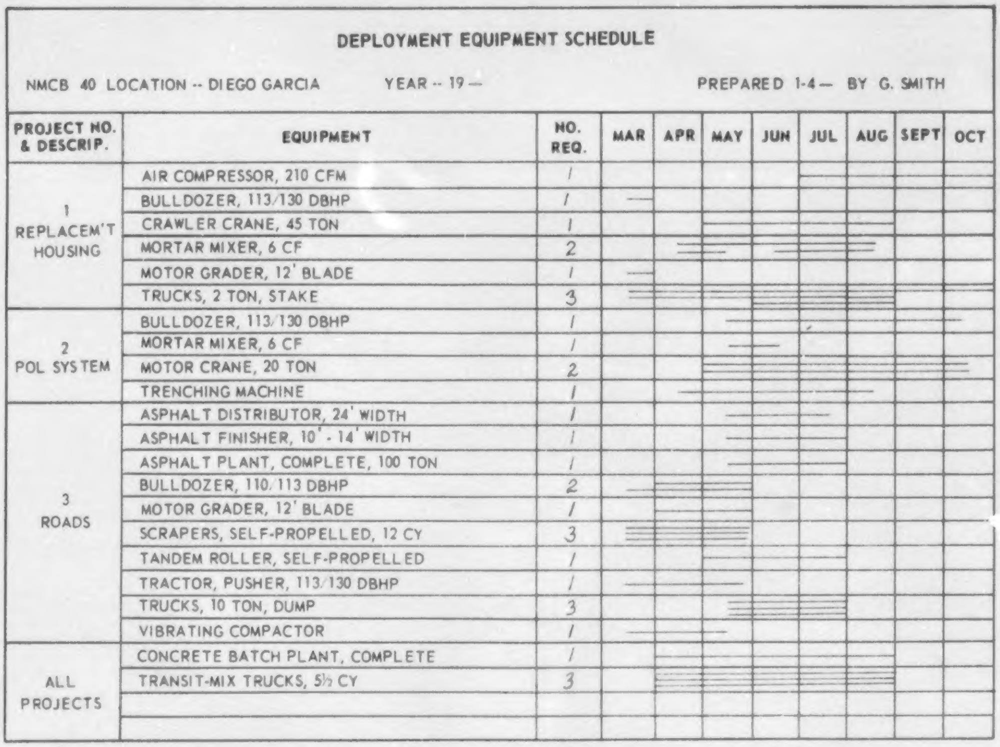
Figure 4-3.—Deployment manpower schedule. 82.93

PROJECT MANPOWER SCHEDULE

NMCG 40 LOCATION -- DIEGO GARCIA YEAR -- 19 — PREPARED 1-4 — BY G. SMITH
PROJECT -- POL SYSTEM

IT. NO.	DESCRIPTION	DATE	JULY																														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2A11	TRENCHING, DITCHING, BACKFILL	E	2	2	2	X	2	X	2	2	2	2	2	2	X	2	2	2	2	2	2	X	7	7	7	7	7	7	X	7	7	7	7
		A																															
2M2	INSTALL VALVES	E			2	X	2	X	2	2					X							X	2	2	2				X				
		A																															
2M4	CONSTRUCT VALVES PITS	E	6	6	6	X	6	X	6	10	5	5	5	6	X	10	6	6	10	6	6	X	6	6	10	5	5	5	X	5	5	10	10
		A																															
2M13	INSTALL 12" PIPE	E	26	26	26	X	26	X	26	26	26	26	26	26	X	26	26	26	26	26	26	X	19	26	22	33	23	26	X	26	26	26	26
		A																															
2R9	PUMP HOUSE	E	12	12	12	X	12	X	12	12	12	12	12	9	X	9	9	9	9	9	9	X	7	7	7	7	10	10	X	10	10	10	10
		A																															
2Q3	WORK NOT COVERED ABOVE	E	4	4		X		X		4	4	4	4	4	X	4						X	2	2	2	2	2	2	X	2	2	2	2
		A																															
		E																															
		A																															
TOTAL PERSONS PER DAY		E	50	50	48	X	46	X	48	56	49	49	49	47	X	51	43	43	47	43	43	X	43	50	50	54	47	50	X	50	50	55	55
		A																															
TOTAL MAN-DAYS PER MONTH		E	1174																														
		A																															

Figure 4-4.–Project manpower schedule. 82.94

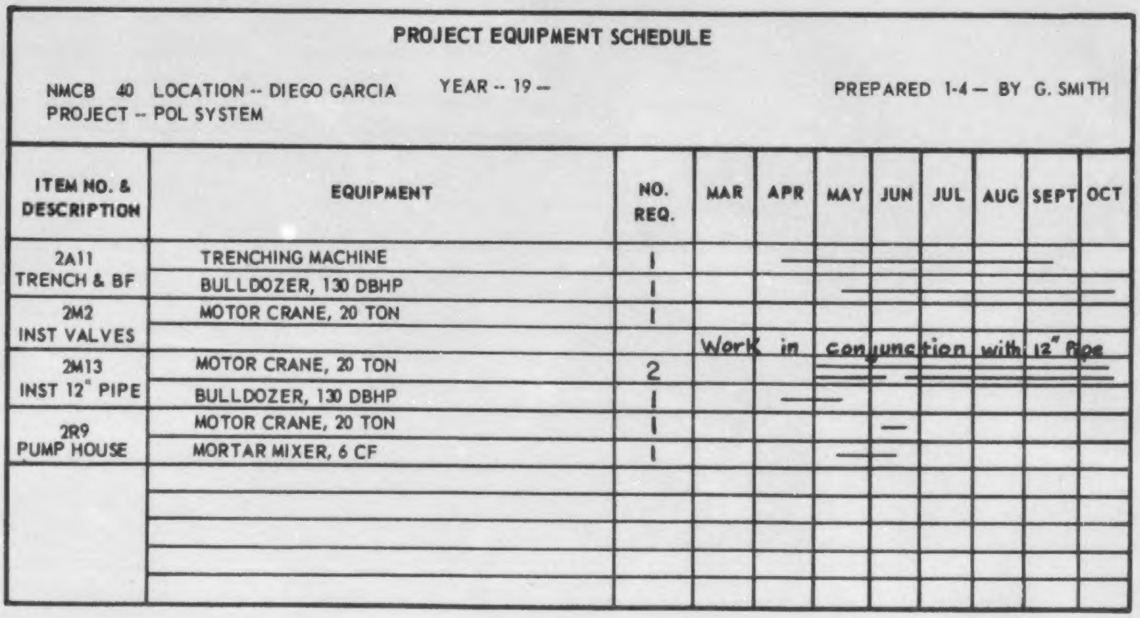


DEPLOYMENT EQUIPMENT SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 19 — PREPARED 1-4 — BY G. SMITH

PROJECT NO. & DESCRIP.	EQUIPMENT	NO. REQ.	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
1 REPLACEM'T HOUSING	AIR COMPRESSOR, 210 CFM	1								
	BULLDOZER, 113/130 DBHP	1								
	CRAWLER CRANE, 45 TON	1								
	MORTAR MIXER, 6 CF	2								
	MOTOR GRADER, 12' BLADE	1								
	TRUCKS, 2 TON, STAKE	3								
2 POL SYSTEM	BULLDOZER, 113/130 DBHP	1								
	MORTAR MIXER, 6 CF	1								
	MOTOR CRANE, 20 TON	2								
	TRENCHING MACHINE	1								
3 ROADS	ASPHALT DISTRIBUTOR, 24' WIDTH	1								
	ASPHALT FINISHER, 10' - 14' WIDTH	1								
	ASPHALT PLANT, COMPLETE, 100 TON	1								
	BULLDOZER, 110/113 DBHP	2								
	MOTOR GRADER, 12' BLADE	1								
	SCRAPERS, SELF-PROPELLED, 12 CY	3								
	TANDEM ROLLER, SELF-PROPELLED	1								
	TRACTOR, PUSHER, 113/130 DBHP	1								
	TRUCKS, 10 TON, DUMP	3								
	VIBRATING COMPACTOR	1								
ALL PROJECTS	CONCRETE BATCH PLANT, COMPLETE	1								
	TRANSIT-MIX TRUCKS, 5½ CY	3								

Figure 4-5.–Deployment equipment schedule. 82.95



PROJECT EQUIPMENT SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 19 — PREPARED 1-4 — BY G. SMITH
PROJECT -- POL SYSTEM

ITEM NO. & DESCRIPTION	EQUIPMENT	NO. REQ.	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
2A11 TRENCH & BF	TRENCHING MACHINE	1		—	—	—	—	—	—	
	BULLDOZER, 130 DBHP	1			—	—	—	—	—	—
2M2 INST VALVES	MOTOR CRANE, 20 TON	1								
			Work in conjunction with 12" Pipe							
2M13 INST 12" PIPE	MOTOR CRANE, 20 TON	2			—	—	—	—	—	—
	BULLDOZER, 130 DBHP	1		—	—					
2R9 PUMP HOUSE	MOTOR CRANE, 20 TON	1				—				
	MORTAR MIXER, 6 CF	1			—	—				

Figure 4-6.—Project equipment schedule. 82.96

PROJECT WORK SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 19 — PREPARED 1-4 — BY G. SMITH
PROJECT -- POL SYSTEM

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	WEIGHTED VALUE	ESTIMATED		ACTUAL	
					START	FINISH	START	FINISH
2A11	TRENCHING, DITCHING, & BACKFILLING	CY	2,200	9.1	4-16 —	10-18 —		
2M2	INSTALL VALVES	EACH	25	0.9	7-16 —	10-16 —		
2M4	CONSTRUCT VALVE PITS	EACH	10	10.9	5-14 —	9-20 —		
2M13	INSTALL 12" PIPE	LF	12,600	58.2	4-30 —	10-16 —		
2R9	PUMP HOUSE	EACH	1	15.4	5-14 —	9-29 —		
2Q3	WORK NOT COVERED ABOVE	L/S	1	5.5	4-16 —	10-18 —		
	TOTAL PROJECT			100.0	4-16 —	10-18 —		

Figure 4-7.—Project work schedule. 82.97

completion dates. Often, of course, it is not economical to wait until one element is finished before starting another. For example: concrete foundations can be started at one end of a building while excavating is still going on at the other end, or paving can begin at one end of a road while grading is still going on at the other.

PROGRESS CONTROL

Progress control is exercised by:

1. Measuring actual production against planned production.
2. Determining causes of discrepancies, if there are any.
3. Taking remedial action to correct deficiencies in production and to balance activities in order to attain overall objectives.

REPORTING PROGRESS

Work accomplished should be reported on daily labor reports. However, in some types of work, it is more convenient to report work quantities as portions are completed, rather than to attempt to report partial completion of portions. For example: if 2,000 cubic feet of earth must be excavated before a section of runway paving is to be placed, it is difficult to estimate partial progress of the excavation, and no report is usually made until the excavation is completed, ready for paving.

Items suitable for daily reporting are those which may reasonably be expected to show a fairly steady production rate per man-hour, such as placing concrete or asphalt paving or excavating and/or hauling of large quantities of cut and fill. For such items, daily reports provide a continuous, running check on progress.

A daily report should show the man-hours expended on each work element. Preparation of weekly or monthly reports is accomplished by recording daily reports in ledger form and totaling for a week or month.

Monthly progress reports are usually made in narrative form, with a progress chart (explained later) included in the report. Major problems affecting progress should be described, and any unusual construction methods should be reported in detail, with sketches included if necessary. If progress is behind schedule, the report should describe what measures are being taken to bring it back on schedule, or explain why the completion date cannot be met and what extension of time is needed for completion.

CHARTING PROGRESS

A common way of charting progress is to insert percentages of actual work completed in spaces left adjacent to the figures for estimated completion percentages on work schedules.

THE NETWORK ANALYSIS METHOD

A network analysis system of project planning, scheduling, and control (called the NETWORK ANALYSIS METHOD) is used widely in the construction field. The object of network analysis is to combine all the information relevant to the planning and scheduling of project functions into a single master plan–a plan that coordinates all the efforts required to accomplish a single objective, that shows the interrelationships of these efforts, that shows which efforts are critical to timely completion, and hence promotes the most efficient use of equipment and manpower.

The following information about network analysis will enable you to prepare arrow diagrams, interpret critical path schedules drawn up for jobs under your supervision, and develop critical path schedules for future construction projects. Arrow diagramming makes up about 80% of the planning phase. Even if only it is done, substantial benefits will be obtained from network analysis.

PREPARING THE ARROW DIAGRAM

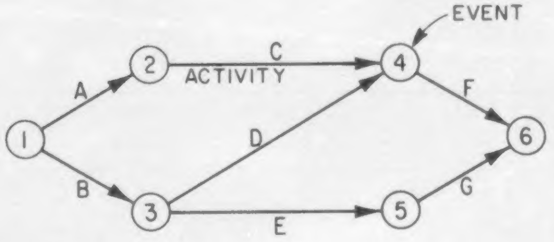
The arrow diagram is the single most important piece of input information. It must be drawn to identify, in a graphic form, the individual items of work, services, or tasks–(referred to in network analysis as

ACTIVITIES)– that are involved in constructing the project. Also, of equal importance, the arrow diagram must show how each ACTIVITY depends upon others during the sequence of construction.

In substance, the arrow diagram graphically describes the sequence of ACTIVITIES as well as the interrelationship of ACTIVITIES within the project. Instead of an arrow diagram, the graphic technique is sometimes referred to as an ARROW NETWORK, a DEPENDENCY DIAGRAM, a DEPENDENCY NETWORK, or a LOGIC NETWORK.

In an arrow diagram, both arrows and circles are used to describe the sequence of work. An arrow represents an ACTIVITY, and a circle represents an EVENT. An EVENT is the starting point of an ACTIVITY and occurs only when all the ACTIVITIES preceding it (which means all the arrows leading to the circle) have been completed.

In figure 4-8, the starting point for activity C is the occurrence of EVENT number (2). Event number (4) does not occur until the work represented by activity C and the work represented by activity D has been completed–and this means entirely completed. This means, then, that the work represented by the activity F cannot start until activities C and D have been finished. If this does not accurately describe the situation, the arrow diagram must be redrawn. The graphic form used to illustrate the arrow diagram is a matter of battalion preference. NAVFAC and COMCBPAC/LANT are somewhat liberal about the form or specific technique used. Three of the more common graphic forms used in arrow diagramming are shown in figure 4-9.



117.308X

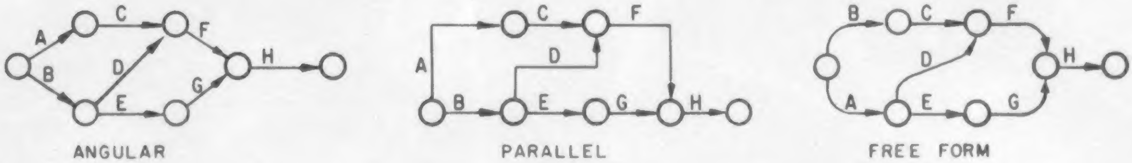
Figure 4-8.–Activities and events.

Because everything that happens in network analysis is activity dependent (one activity is dependent upon others), the arrow diagram must be a meaningful description of the project. If it is not, less than satisfactory results will be obtained from the network analysis. In almost every case of difficulty or dissatisfaction with network analysis, the cause can be traced to a faulty or unrealistic arrow diagram. Since everything in an arrow diagram is significant, the basic principles must be understood and applied completely.

Principle Number 1

The first principle of arrow diagram development is that everything in the diagram has meaning. Within this principle, the following rules apply.

1. Every arrow represents an item of work and is referred to as an ACTIVITY. (See view A of fig. 4-10.)



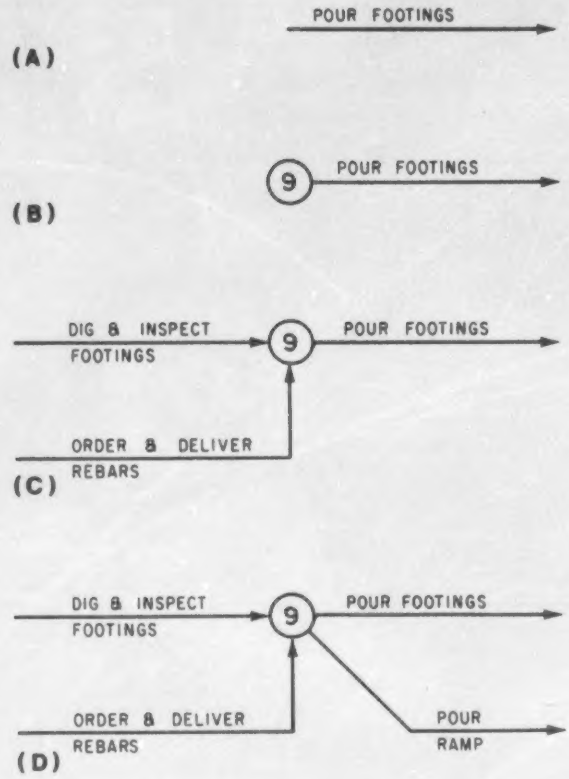
ANGULAR

PARALLEL

FREE FORM

117.309X

Figure 4-9.–Graphics forms used in arrow diagramming.


(A)
POUR FOOTINGS
(B)
9
POUR FOOTINGS
(C)
DIG & INSPECT FOOTINGS
9
POUR FOOTINGS
ORDER & DELIVER REBARS
(D)
DIG & INSPECT FOOTINGS
9
POUR FOOTINGS
ORDER & DELIVER REBARS
POUR RAMP

143.290X

Figure 4-10.—Diagram development for principle number 1.

2. An EVENT is the starting point of an ACTIVITY, shown as a circle. (See view B of fig. 4-10.)

3. An ACTIVITY depends upon and cannot begin until the completion of all preceding ACTIVITIES. (See view C of fig. 4-10.)

As illustrated in view D of fig. 4-10, POUR FOOTINGS depends upon the completion of DIG & INSPECT FOOTINGS and ORDER & DELIVER REBARS.

4. All activities that start with the same event depend upon and cannot begin until the completion of all activities that enter that event.

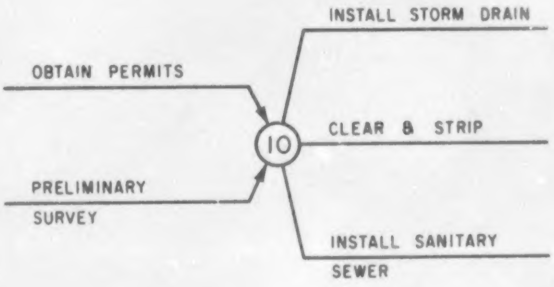
As illustrated in view D of fig. 4-10, POUR FOOTINGS and POUR RAMP depend upon the completion of the two activities that enter their common starting event. In other words, it is impossible to POUR FOOTINGS or to POUR RAMP until DIG & INSPECT FOOTINGS, and ORDER & DELIVER REBARS have both been completed. The diagram indicates that all the footings (not just some) must be dug and inspected, and all necessary rebars must be on hand, before either of the two activities starting with event (9) can begin.

In figure 4-11, all three activities that start with event (10) must wait until all activities that enter event (10) have been entirely completed. None of the three can possibly start until both OBTAIN PERMITS and PRELIMINARY SURVEY have been finished. If one of the three leaving (10) does not depend upon the completion of both those entering (10), the arrow diagram is misdrawn and the schedules produced from it will not be realistic.

Principle Number 2

A second principle is that an activity has a single definite starting point and a single definite ending point. Placing an arrow in a diagram must satisfy two basic questions:

1. "What activities must be completed before this one can start?" This indicates the event from which to start the activity.


OBTAIN PERMITS
PRELIMINARY SURVEY
10
INSTALL STORM DRAIN
CLEAR & STRIP
INSTALL SANITARY SEWER

117.314X

Figure 4-11.—Three activities starting at a common event.

2. "What activities cannot be started if this one is not completed?" This indicates into which event the activity should enter.

Suppose, for example, the following arrow diagram (fig. 4-12) had been drawn.

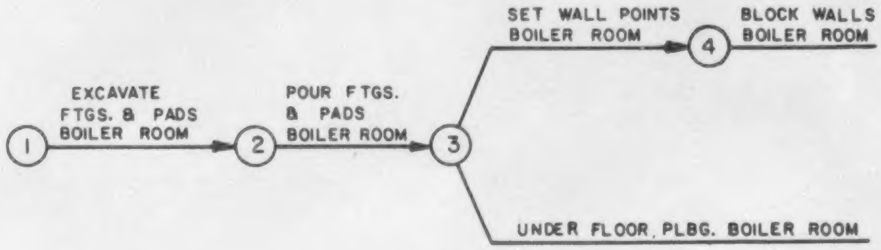
As shown excavating for the footings and pads for the Boiler Room is the first activity, followed by placing the concrete footings and pads. At event (3) and as a result of the completion of the previous activities, several independent work items then can commence.

Suppose, however, that it is desired to add an activity to indicate delivery of concrete block for the walls of the boiler room. The first question asked about this new activity should be, "What must be finished before the block can be ordered and delivered?" Actually, there is nothing in the diagram that–if not accomplished–would hold up the ordering and delivery of block. The starting point for this activity would then be event (1).

The second question to be asked about the new activity is, "What cannot proceed until this activity is completed?" The answer is, of course, BLOCK WALLS, BOILER ROOM. The termination point for this new activity then is event (4) and the results of the analysis described above would appear as illustrated in figure 4-13.

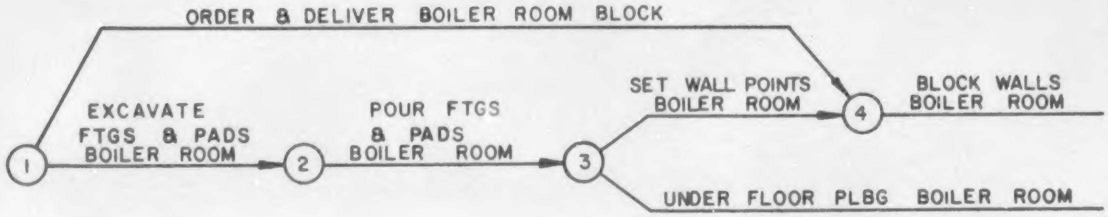
Principle Number 3

A third principle is that the arrow diagram does not describe time relationships, but rather dependency relationships. Generally, the arrow diagram is not drawn on a time scale. That is, the length and direction of an activity arrow has no relationship to the amount of time required to accomplish the work represented by it. Likewise, two activities starting with the same


SET WALL POINTS
BOILER ROOM
BLOCK WALLS
BOILER ROOM
4
EXCAVATE
FTGS. & PADS
BOILER ROOM
POUR FTGS.
& PADS
BOILER ROOM
1
2
3
UNDER FLOOR. PLBG. BOILER ROOM

117.315X

Figure 4-12.–Diagram development.


ORDER & DELIVER BOILER ROOM BLOCK
SET WALL POINTS
BOILER ROOM
4
BLOCK WALLS
BOILER ROOM
EXCAVATE
FTGS & PADS
BOILER ROOM
POUR FTGS
& PADS
BOILER ROOM
1
2
3
UNDER FLOOR PLBG BOILER ROOM

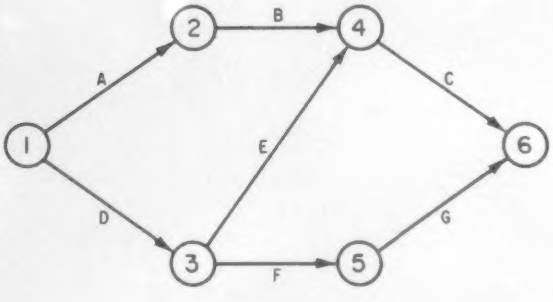
117.316X

Figure 4-13.–Adding an activity.

event do not necessarily occur at the same time. In figure 4-14, the only thing known about activities A and D is that they are independent. They may or may not go on at the same time. The time that an activity takes place is decided in the Scheduling Phase, not by the arrow diagram. The arrow diagram merely defines the dependency situations that exist. In the illustration involving the concrete block for the boiler room walls, for example, the activity ORDER & DELIVER BOILER ROOM BLOCK starts with event (1), as does EXCAVATE FOOTINGS & PADS, etc. This does not mean that both activities must be conducted at the same time. They might but probably won't. The only thing indicated is that these two activities are independent.

Principle Number 4

It is important to realize that the arrow diagram is seldom drawn by a single person. Because the accomplishment of the schedule produced from the arrow diagram is affected by many persons, all who have anything to do with the project must be consulted when the arrow diagram is created. All crew leaders should be asked to review the arrow diagram carefully to make certain that the activities pertaining to their work are accurately and realistically described. Also, this principle applies equally to the production of duration estimates for the activities.



117.317X

Figure 4-14.–Dependency relationship.

OTHER RULES AND CONVENTIONS

Notice in the illustrations thus far, that the events are all numbered. Numbering makes it possible to uniquely identify an activity–and its position in the diagram. An activity is identified by using the event number at its tail (called the activity's "I") and the event number at its head (called the activity's "J"). In the boiler room illustration, POUR FOOTINGS & PADS–BOILER ROOM could be referred to or identified as activity (2)–(3).

So that an activity can be uniquely identified by its "I" and "J" numbers, a rule must be established and observed in the creation of the arrow diagram. The rule can be stated as follows:

"NOT MORE THAN ONE ACTIVITY MAY HAVE THE SAME 'I' AND THE SAME 'J'."

To help observe this rule, it is sometimes necessary to use a "connector" type activity that doesn't really represent work. This type of activity (usually referred to as a DUMMY) is drawn as a dotted line. It indicates that no work is involved in that activity.

Figure 4-15 illustrates this rule and the use of the dotted-line (dummy) activity. The dotted-line activity represents the dummy and

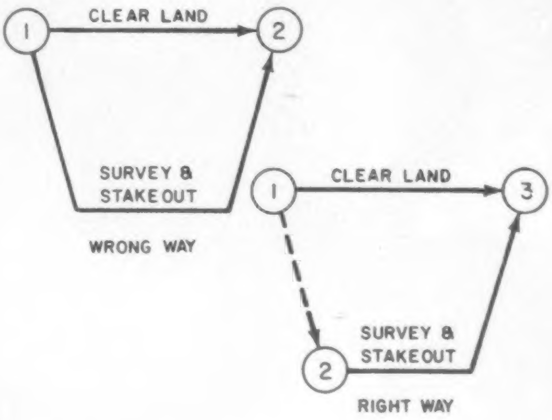


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Figure 4-15.–Activity identification.

involves no duration and no cost. It serves only as a dependency connector or sequence indicator.

Dummies have purposes in addition to the one mentioned above, and will be discussed in more detail later.

To produce a schedule by hand, you must make sure of two things that concern the numbering of events: (1) every number must be used, and (2) the number at the tail of an arrow must be less than the number at the head of that arrow.

It is always wise to refrain from numbering the diagram until it has been completed, reviewed, and approved.

Another rule governing the creation of the arrow diagram is that a project will have only one starting event and only one ending event. When nothing must be done prior to the start of an activity, the arrow representing that activity starts with the project's starting event. When nothing depends upon the accomplishment of an activity, its arrow ends with the project's ending event. Because of this rule, you always know where an activity belongs in the network. Furthermore, restricting the arrow diagram to one starting event and one ending event does not limit the number of starting or ending activities.

ARROW DIAGRAM CONSTRUCTION PROBLEMS

This section is devoted to the solution of problems by network analysis and arrow diagramming. In problem solving, it is vital to draw properly the arrow diagram upon which network analysis is based. To do so, you must apply the basic principles of diagram preparation that are repeated here:

- Everything in the arrow diagram has significant meaning.

- An activity has a single definite starting point, and a single definite ending point.

- The arrow diagram describes dependency relationships rather than time relationships.

Moreover, in applying the second principle above, you must ask two questions and know the answers to both. What activities must be completed before this one can start? What activities cannot start until this one has been completed? The answer to the first question determines the event that starts the activity, whereas the answer to the second indicates at what event the activity ends.

PROBLEM 1

To illustrate the arrow diagram with an actual problem, suppose that it was desired to install a drainage ditch in the backyard of a house. Assume for this problem that only one person was going to work on this project. Draw a diagram for this project including only the following activities:

1. DIG DITCH

2. PLACE GRAVEL IN BOTTOM OF DITCH

3. OBTAIN DRAINTILE

4. INSTALL DRAINTILE AND BACKFILL

Make the following assumptions about these activities:

A. There is no need to order or deliver gravel. There is a supply in the driveway.

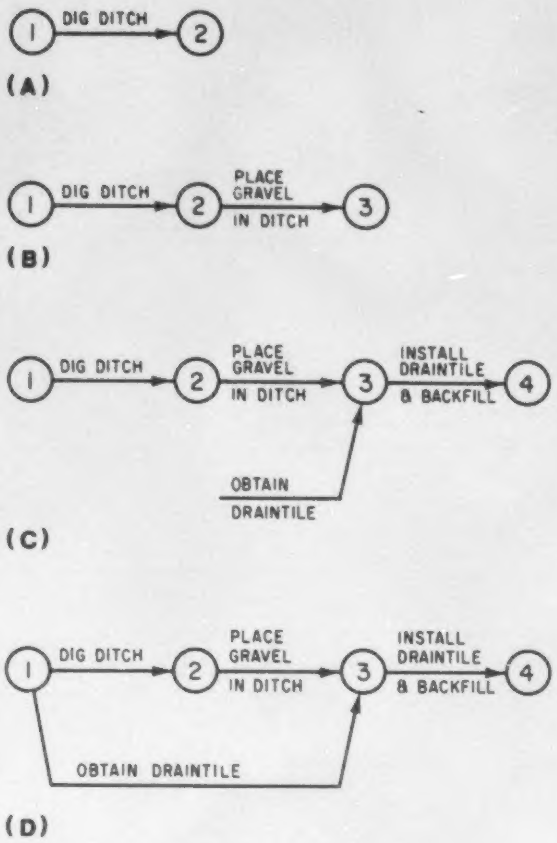
B. OBTAIN DRAINTILE does not require the effort of the one person doing this project. It is a "delivery" type activity.

The first activity possible in this project is DIG DITCH—so an activity indicating this would be drawn as illustrated in view A of fig. 4-16.

After the ditch had been dug, the placing of the gravel would be next and the diagram would look like view B of fig. 4-16.

After the gravel is in, the draintile could be installed. However, in order for this to happen, the draintile must have been obtained. This means that the activity OBTAIN DRAINTILE must end at the beginning of INSTALL

80



143.291

Figure 4-16.–Diagram development for problem 1.

DRAINTILE AND BACKFILL. This will be at event (3) and the diagram would look like view C of fig. 4-16.

The question remaining is where does OBTAIN DRAINTILE start? One must further ask what activities must be accomplished before this one can start. It turns out that nothing need be done in order to start this activity and it thus starts with event (1). The completed solution is illustrated in view D of fig. 4-16.

PROBLEM 2

To create a slightly more complicated problem, consider the situation that would exist if the work described in problem 1 had been performed in the street in front of the house rather than in the backyard.

If this were the case, it would be necessary to add to the list of activities given for 1, the following:

5. OBTAIN PERMIT TO BLOCK STREET
6. BLOCK STREET
7. OBTAIN TRENCHER
8. ORDER AND DELIVER PAVING MATERIAL
9. PAVE STREET

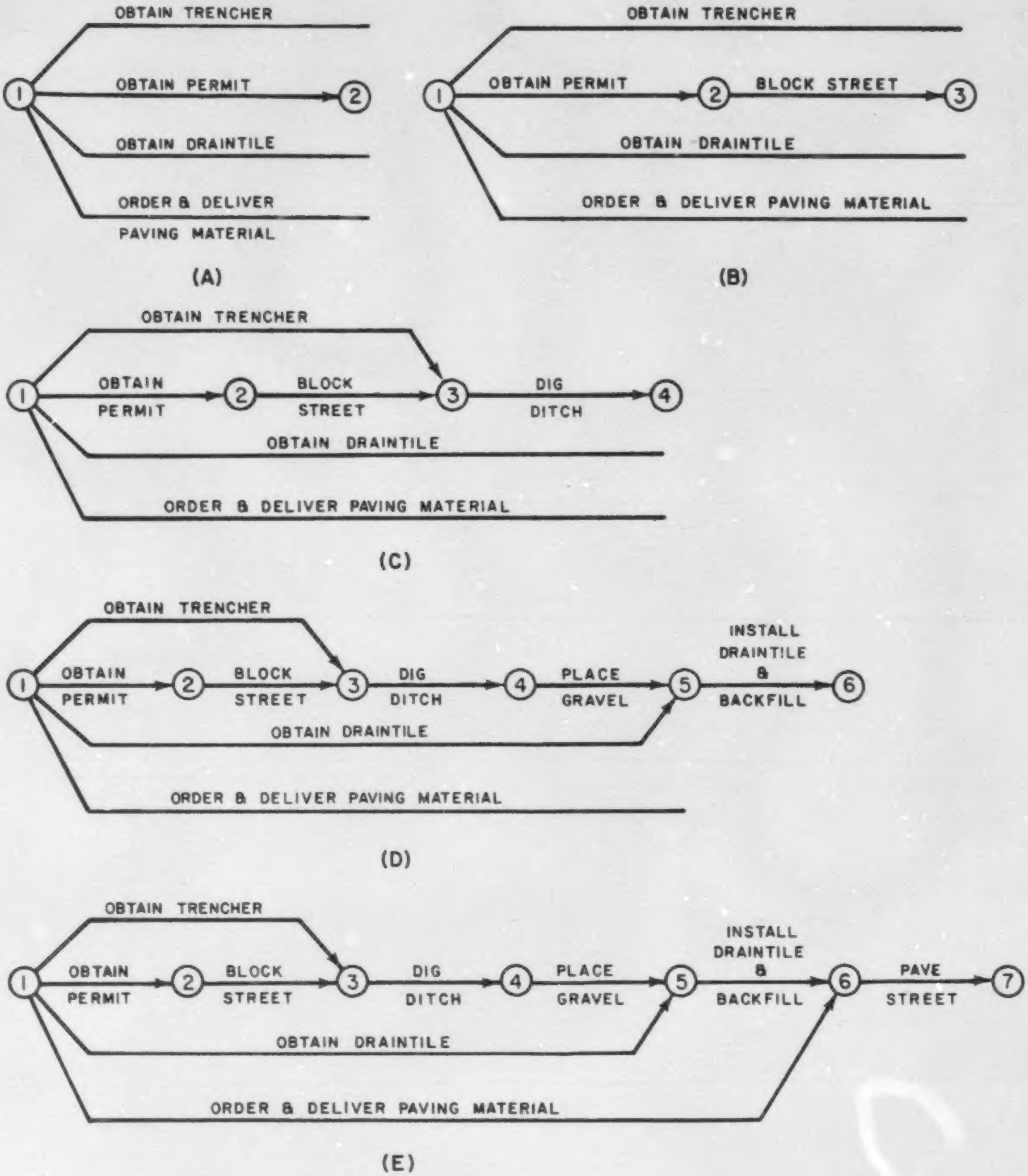
For this problem, the following assumptions are made in addition to A & B already mentioned in problem 1:

C. The permit is only necessary to block the street. There is no doubt that it will be obtained.

D. OBTAIN TRENCHER is a delivery type activity just as OBTAIN DRAINTILE was in problem 1.

The solution to this problem would start with the first activity that can take place. In this problem, four independent activities can be shown as starting the project. (See view A of fig. 4-17). Which one goes where, is not at all important. In the beginning, it may appear that all four activities are expected to start or take place at the same time. This is definitely not the case. The person drawing the diagram must realize and remember at all times that the arrow diagram does not describe time relationships but rather only dependencies. This diagram, so far, states only that OBTAIN TRENCHER, OBTAIN PERMIT, OBTAIN DRAINTILE, and ORDER AND DELIVER PAVING MATERIAL are independent, that is, can start at any time whether activities have started or not. "When" these activities take place will be determined in the scheduling phase.

The next item that can be placed into the diagram is BLOCK STREET. The only thing that must be done before this activity can start


OBTAIN TRENCHER
OBTAIN PERMIT
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
1
2
(A)
OBTAIN TRENCHER
OBTAIN PERMIT
BLOCK STREET
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
1
2
3
(B)
OBTAIN TRENCHER
OBTAIN PERMIT
BLOCK STREET
DIG DITCH
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
1
2
3
4
(C)
OBTAIN TRENCHER
OBTAIN PERMIT
BLOCK STREET
DIG DITCH
PLACE GRAVEL
INSTALL DRAINTILE & BACKFILL
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
1
2
3
4
5
6
(D)
OBTAIN TRENCHER
OBTAIN PERMIT
BLOCK STREET
DIG DITCH
PLACE GRAVEL
INSTALL DRAINTILE & BACKFILL
PAVE STREET
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
1
2
3
4
5
6
7
(E)

117.323X

Figure 4-17.—Diagram development for problem 2.

is OBTAIN PERMIT. This new activity then starts with event (2) as shown in view B of figure 4-17.

The assumption that obtaining the permit was only a formality makes it possible to show OBTAIN TRENCHER, OBTAIN DRAINTILE and the PAVING MATERIAL ACTIVITY as starting with event (1). If this assumption had not been made, a prudent decision would have been to start these activities at event (2) so as to avoid spending money without being sure of the results.

After the street had been blocked, DIG DITCH could start. However, because the ditch is to be dug through the pavement, the trencher would have to be on hand. The arrow diagram indicating this would appear as shown in view C of figure 4-17.

From this point until the final activity, the diagram would be constructed as it was for problem 1, as shown in view D of figure 4-17.

The final activity would be the repair to the damage caused by tearing up the street. In order to pave, however, the paving materials would have to be on hand. This situation is described by making the event that starts PAVE STREET (6) and making the same event the end point for ORDER AND DELIVER PAVING MATERIAL. The final solution to this problem is illustrated in view E of figure 4-17.

An important point to remember about arrow diagrams is that the assumptions made about the activities are as important as the activities themselves. They should always be written down, so as to be remembered.

PROBLEM 3

Create an arrow diagram for a reinforced concrete equipment foundation project to be built partially below ground level. Assume that all necessary tools, equipment and materials (including concrete) are on the job site, and that there is no limit to the number of workers. A backhoe is used to excavate. Use only the following activities:

1. LAY OUT AND EXCAVATE
2. FINE GRADE
3. PREFABRICATE FORMS
4. PREFABRICATE REBAR
5. SET FORMS
6. SET REBAR AND ANCHOR BOLTS
7. ADVISE AVAILABILITY OF BACKHOE
8. POUR CONCRETE

For this problem, assume that FINE GRADE must be done before the forms are set.

One would start the arrow diagram with three independent activities as indicated in view A of figure 4-18. Remember that the diagram does not indicate that these three items go on at the same time. It only shows that they are not dependent on the completion of any other activities.

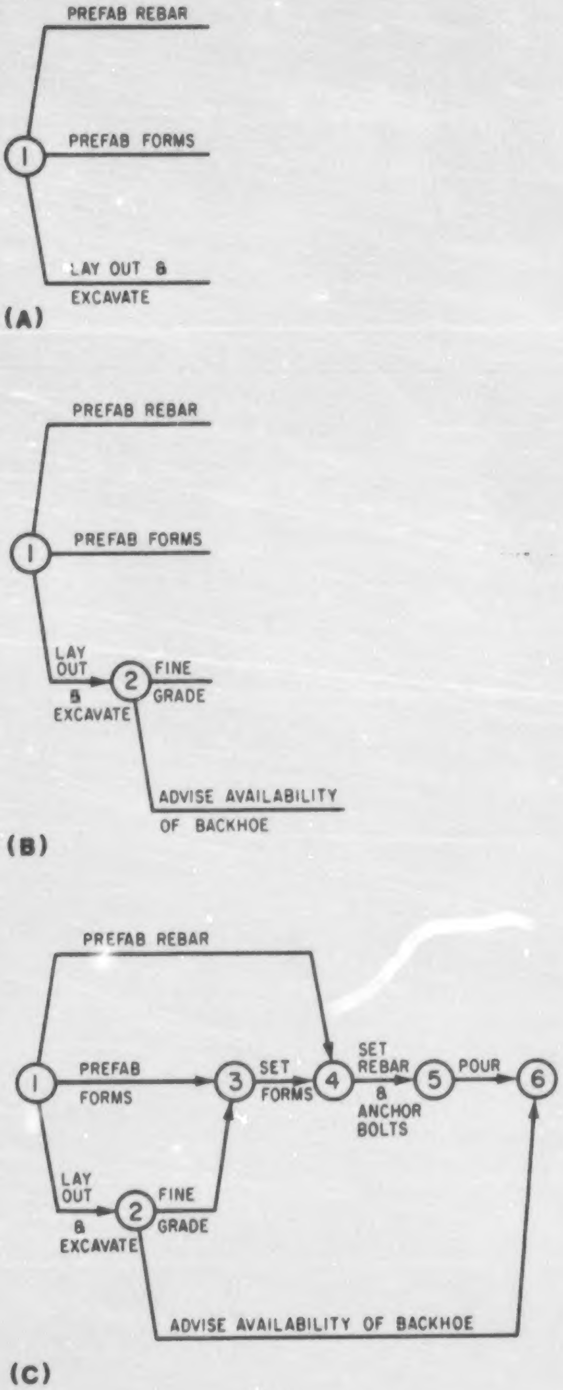
After the layout and excavation had been completed, two activities could be started. FINE GRADE would depend upon the completion of this activity, and of course, the backhoe could not be returned until the completion of this phase of work. At this point the diagram would appear as indicated in view B of figure 4-18.

Again, the diagram IS NOT stating that FINE GRADE and that ADVISE AVAILABILITY OF BACKHOE occur simultaneously, but rather that they both depend upon–cannot start until–the completion of LAYOUT AND EXCAVATE.

After FINE GRADE had been completed, and when PREFAB FORMS was finished, SET FORMS could start. At its conclusion, and after PREFAB REBAR had been completed, it would be possible to SET REBAR and ANCHOR BOLTS and then finally POUR. The final arrow diagram would look like view C of figure 4-18.

DUMMIES

Occasionally, it is necessary to use a "connector" type activity to indicate a dependency relationship without causing


PREFAB REBAR
1
PREFAB FORMS
LAY OUT &
EXCAVATE
(A)
PREFAB REBAR
1
PREFAB FORMS
LAY
OUT
& EXCAVATE
2
FINE
GRADE
ADVISE AVAILABILITY
OF BACKHOE
(B)
PREFAB REBAR
1
PREFAB
FORMS
3
SET
FORMS
4
SET
REBAR
&
ANCHOR
BOLTS
5
POUR
6
LAY
OUT
&
EXCAVATE
2
FINE
GRADE
ADVISE AVAILABILITY OF BACKHOE
(C)

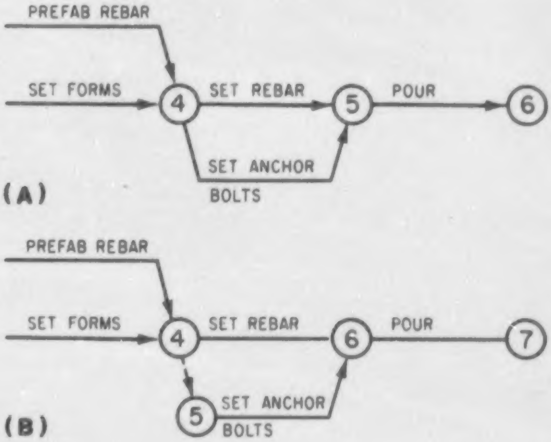
117.324X

Figure 4-18.—Diagram development for problem 3.

confusion. This type of activity, which does not represent work and which has a duration of zero, is called a DUMMY activity and is shown on the arrow diagram as a dotted line.

There are two reasons for using dummies. These two reasons can be illustrated by altering problem 3 above. Suppose that instead of having a single activity called SET REBAR AND ANCHOR BOLTS, it was desired to make two activities: one called SET REBAR and the other called SET ANCHOR BOLTS. Suppose that both depended upon PREFAB REBAR, and SET FORMS, and that both had to be completed before the POUR. The affected part of the diagram would appear as illustrated in view A of figure 4-19.

From a dependency point of view, there is nothing wrong with this kind of description. However, confusion results from having more than one activity with the same I–J numbers. It is not clear which is activity (4)–(5). Earlier in this chapter a rule was established to solve this problem. It was stated that not more than one activity may have the same "I" and the same "J". So as not to break this rule, one of the two "non-unique" activities must be changed into two, one of which is a dummy. The affected


PREFAB REBAR
SET FORMS
4
SET REBAR
5
POUR
6
SET ANCHOR
BOLTS
(A)
PREFAB REBAR
SET FORMS
4
SET REBAR
6
POUR
7
5
SET ANCHOR
BOLTS
(B)

117.325X

Figure 4-19.—Using a dummy to maintain the uniqueness of the I-J identification system.

part of the diagram would now appear as illustrated in view B of figure 4-19.

If view B of figure 4-19 is examined closely, the following points become clear:

1. Event (6) occurs when SET REBAR and SET ANCHOR BOLTS have been completed.

2. Since the DUMMY from (4) to (5) activity has zero duration, it is completed at the same point in time that event (4) occurs.

3. For this reason, event (5) occurs when SET FORMS is finished and PREFAB REBARS is finished, and SET ANCHOR BOLTS can start at this time.

4. This is exactly the same dependency statement that was made in the incorrect solution illustrated in view A of figure 4-19 in which two activities from (4)–(5) appeared.

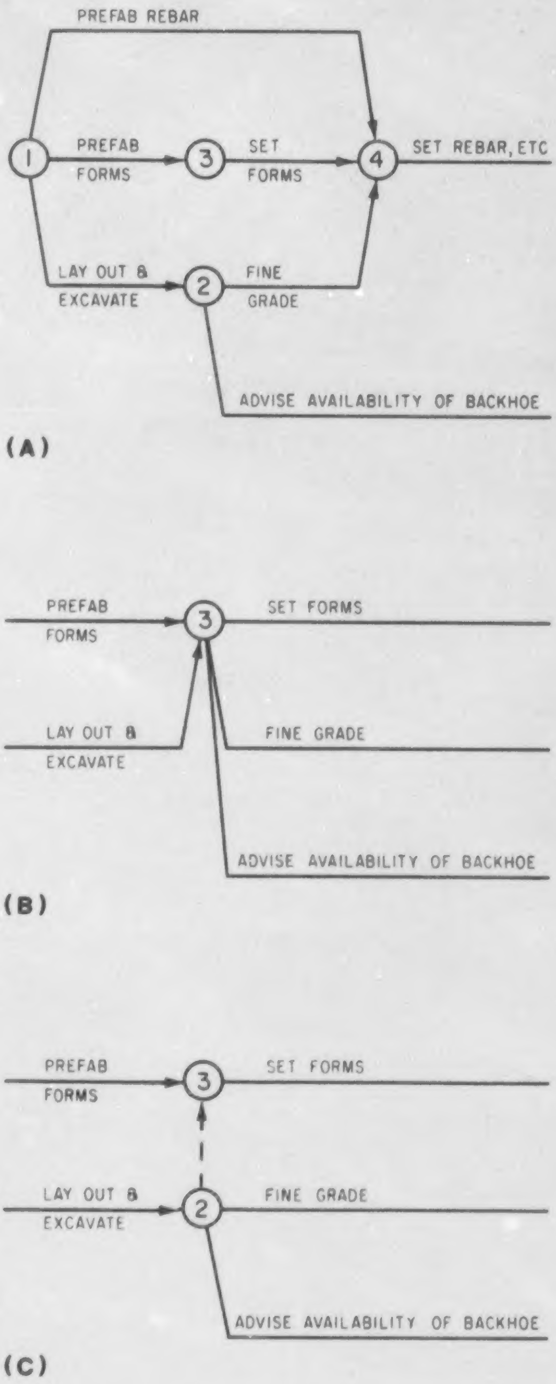
The first reason for using a dummy then is to maintain the uniqueness of the I–J identification system.

The second reason for using a dummy is somewhat more complex. A connector type activity is sometimes needed to describe dependencies in such a way that non-dependent activities are not shown as dependent. This can be illustrated also with the diagram from problem 3.

If the problem were changed by eliminating the assumption that FINE GRADE had to precede the setting of the forms, one would be tempted to produce an arrow diagram that looked like view A of figure 4-20.

This approach, however, is incorrect because it is not possible to SET FORMS unless at least the excavating has been completed. Another solution—which is also incorrect—might be to combine event number (2) and event (3). Event (3) would then appear as in view B of figure 4-20.

The error in this arrow diagram exists because FINE GRADE and ADVISE AVAILABILITY OF BACKHOE do not depend


PREFAB REBAR
1
PREFAB
FORMS
3
SET
FORMS
4
SET REBAR, ETC
LAY OUT &
EXCAVATE
2
FINE
GRADE
ADVISE AVAILABILITY OF BACKHOE
(A)
PREFAB
FORMS
3
SET FORMS
LAY OUT &
EXCAVATE
FINE GRADE
ADVISE AVAILABILITY OF BACKHOE
(B)
PREFAB
FORMS
3
SET FORMS
LAY OUT &
EXCAVATE
2
FINE GRADE
ADVISE AVAILABILITY OF BACKHOE
(C)

117.326X

Figure 4-20.—Using a dummy to establish a dependency or sequence without confusing non-dependent activities.

upon the completion of PREFAB FORMS as indicated, but rather only on LAY OUT AND EXCAVATE.

The correct solution is one in which SET FORMS is indicated as depending upon both PREFAB FORMS as well as on LAY OUT AND EXCAVATE, and in which FINE GRADE and ADVISE AVAILABILITY OF BACKHOE depend only on LAY OUT AND EXCAVATE. The proper way to show this situation is by using the first solution with a DUMMY from (2) to (3), as illustrated in view C of figure 4-20.

Because the DUMMY from (2) to (3) has a zero duration, it is finished when event (2) occurs. It merely transfers, then the dependency relationship—the sequence—desired to event (3).

The second reason for using a DUMMY is to establish a dependency or sequence without confusing non-dependent activities.

DUMMY PROBLEM

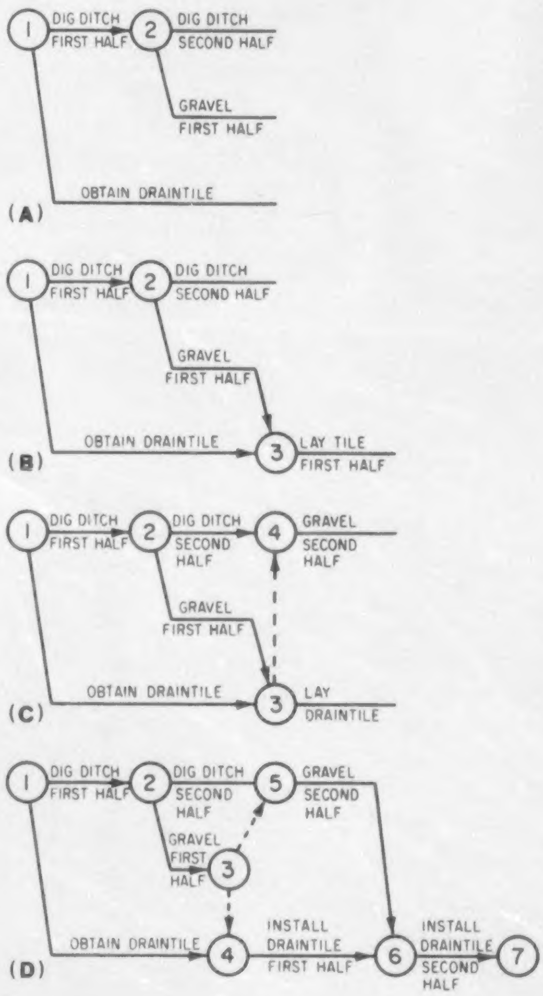
Go back to the very first problem in this section. There it was assumed that only one person would work on the job. If the job is broken into segments to show how several crews would get the job done, the activity list could be almost doubled. Assume for this problem that each of those original activities will now be done each in two phases. That is, approximately half the ditch will be dug before the "gravel crew" will start placing gravel, and the gravel will be in half the ditch before the crew installing the draintile can start work. The activity list would then consist of the following items:

1. OBTAIN DRAINTILE
2. DIG DITCH FIRST HALF
3. DIG DITCH SECOND HALF
4. PLACE GRAVEL FIRST HALF
5. PLACE GRAVEL SECOND HALF
6. INSTALL DRAINTILE FIRST HALF
7. INSTALL DRAINTILE SECOND HALF

It must be assumed for this problem that the first half of each job will be finished before the second half starts. Assumed also is that OBTAIN DRAINTILE is a delivery type of activity, and that the ditch will be backfilled as part of the INSTALL DRAINTILE operation.

The initial activities would be drawn in as illustrated in view A of fig. 4-21.

This arrangement of activities indicates that when DIG DITCH FIRST HALF is complete,


(A)
1
DIG DITCH FIRST HALF
2
DIG DITCH SECOND HALF
GRAVEL FIRST HALF
OBTAIN DRAINTILE
(B)
1
DIG DITCH FIRST HALF
2
DIG DITCH SECOND HALF
GRAVEL FIRST HALF
OBTAIN DRAINTILE
3
LAY TILE FIRST HALF
(C)
1
DIG DITCH FIRST HALF
2
DIG DITCH SECOND HALF
4
GRAVEL SECOND HALF
GRAVEL FIRST HALF
OBTAIN DRAINTILE
3
LAY DRAINTILE
(D)
1
DIG DITCH FIRST HALF
2
DIG DITCH SECOND HALF
5
GRAVEL SECOND HALF
GRAVEL FIRST HALF
3
OBTAIN DRAINTILE
4
INSTALL DRAINTILE FIRST HALF
6
INSTALL DRAINTILE SECOND HALF
7

143.292

Figure 4-21.—Diagram development for expanded drainage ditch problem.

two activities can start. DIG DITCH SECOND HALF and GRAVEL FIRST HALF. Independently, OBTAIN DRAINTILE can occur any time after the start of the project.

When the gravel is in the first half of the ditch, if the draintile is on hand, the draintile can be installed. The diagram would grow to look like view B of fig. 4-21.

When the second half of the ditch had been dug, the gravel could be placed. However, the assumption was made that the first half of any job would have to be completed before starting the second half. This causes a problem insofar as the present version of the diagram is concerned. It is desired to show that GRAVEL SECOND HALF depends upon DIG DITCH SECOND HALF and GRAVEL FIRST HALF. Tying this new activity to the ditch digging operation is no problem but difficulties arise when GRAVEL FIRST HALF is considered. The problem is caused by the fact that GRAVEL FIRST HALF has been tied into event (3). If the end of GRAVEL FIRST HALF is connected to the beginning of GRAVEL SECOND HALF, and a dummy is about the only way this could be done, a serious sequence error is committed.

The diagram, as it appears in view C of fig. 4-21, indicates that GRAVEL SECOND HALF cannot start until OBTAIN DRAINTILE has been completed. That is, the diagram states that it is impossible to place gravel unless draintile is on hand. No such assumption was made, so this is incorrect.

The problem is solved by rearranging the diagram as originally created and splitting GRAVEL FIRST HALF into two paths. Dummy activities are, of course, required to do this. The final solution to this expanded drainage ditch problem appears in view D of fig. 4-21.

NETWORK ANALYSIS SCHEDULING

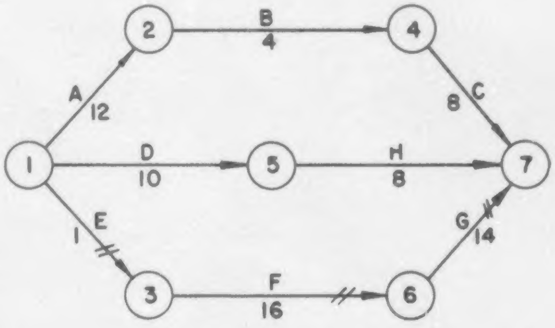
After a project has been planned on an arrow diagram, the next phase is to schedule the project–that is, place it on a working timetable. This makes it possible to determine when each of the various activities must be performed, when deliveries must take place, how much (if any) spare time there is for each activity, and when completion of the project may be expected. It will also be possible to determine which activities are critical, and to what extent a delay in one activity will affect succeeding activities. The steps taken in this phase determine whether or not network analysis will be used successfully.

DURATION ESTIMATES

Developing a schedule for a project involves estimating the time it will take to complete each activity, called the duration time. Duration time estimates are also used to identify activities that control the time needed to finish the project. These are the critical activities that collectively make up the "critical path", which is the longest path–in terms of time–through the network. Since duration times of critical activitites are added to determine the duration of the project, delaying a critical activity will increase the total duration time. Conversely, speeding up a critical activity will decrease the total duration time.

Duration estimates can be made in several ways, but always on an individual activity basis. The simplest way is to determine the "normal" amount of time needed to finish the activity, and assuming that the usual number of crew members or pieces of equipment are available.

In the arrow diagram of figure 4-22, duration times have been assigned to each of the activities. This diagram contains three paths, one of which consists of activities A, B, and C. It



117.332X

Figure 4-22.–Determining the critical path.

indicates that A, a 12-day activity, must be finished before 4-day activity B can begin, and that B must be finished before 8-day activity C can start. The time required to complete these activities equals the total of their duration times (12 + 4 + 8) or 24 days.

A second path through this network is made up of activities E, F, and G. This path requires a total of 31 days to finish, (1 +16 + 14).

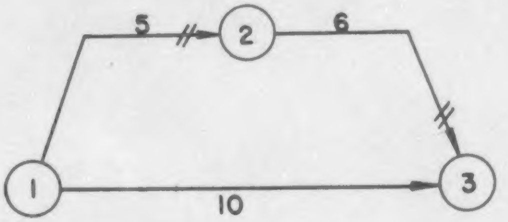
A third path in the network is also possible. It is made up of activities D and H. The duration of this path is 10 + 8, or 18 days.

The longest path in time through the network illustrated is thus E, F, and G. This then is the critical path and is indicated by small double slants on the arrows. If it is desired or required that the amount of time needed to complete the project be shortened, these are the activities upon which to concentrate. Non-critical activities are strictly dependent upon the completion of the critical items, so speeding up non-critical activities is of no value at all, in terms of project duration.

It turns out generally that a very small number of activities make up the critical path–usually less than thirty per cent of the total activities. This means that a large percentage of the activities in a project have extra time available–since they are, in a sense, waiting for the critical items to be completed. A project manager can adjust non-critical activities to take best advantage of weather conditions, manpower and equipment availabilities, and other items, without delaying the project.

An important point to remember in network analysis is that there is not necessarily only one critical path. There may be serveral. Also, remember that if a critical path is shortened, a new "parallel" path will most likely become critical. In the simplified example illustrated in figure 4-23, the critical path goes through the top activities. If these are shortened by only one day, however, the bottom path becomes a parallel critical path. Any further reducing of the amount of time required to get the project finished would have to be done on both critical paths.

In studying an arrow diagram, project managers and others want to pick out important or significant conditions or events quickly. To enable them to do this, you may be asked to identify the key events as "milestones." A MILESTONE may be indicated by the use of a slightly different symbol, or may be shown as a regular event with a special notation on the diagram as to its significance, such as "interior wiring completed" or "roof completed".



117.333X

Figure 4-23.–Simplified example.

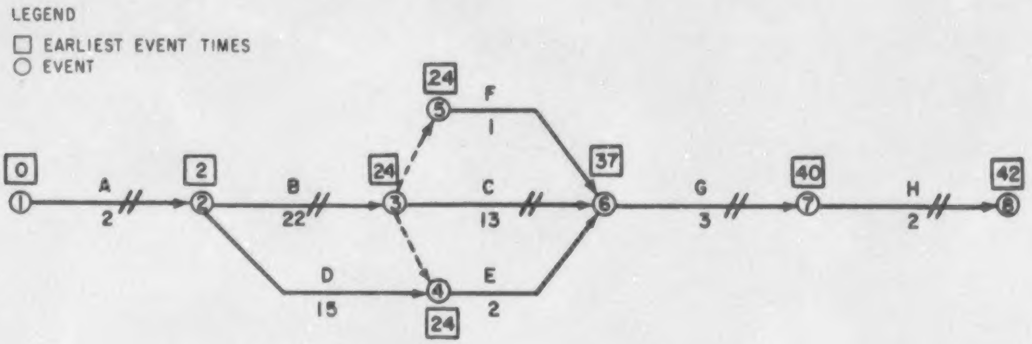
EARLIEST EVENT TIMES

The earliest time at which an event can occur is the sum of the durations of the activities on the LONGEST PATH leading up to the event. This time is entered in a box next to the event on the arrow diagram, as shown in figure 4-24.

The times shown are, of course, project times–that is, successive WORKING days, not successive calendar days, reckoned from 0 at the tail of the first arrow. The duration of the first activity in figure 4-24 is 2 days; therefore, event (2) occurs at project time 2. The time for event (3) is the sum of the duration times of activities (1)–(2) and (2)–(3) or 24. However, there are two paths leading to event (4): one from event (1) through (2) for a total of 17, the other from event (1) through (2) and (3) for a total of 24. Following the rule of selecting the longest path, the earliest event time for event (4) is 24. Similarly, three paths lead to event (6), and the longest from event (1) through (2) and (3) is selected, giving an earliest event time for event (6) of 37.

LATEST EVENT TIMES

To calculate latest event times, you start with the last event on the arrow diagram and

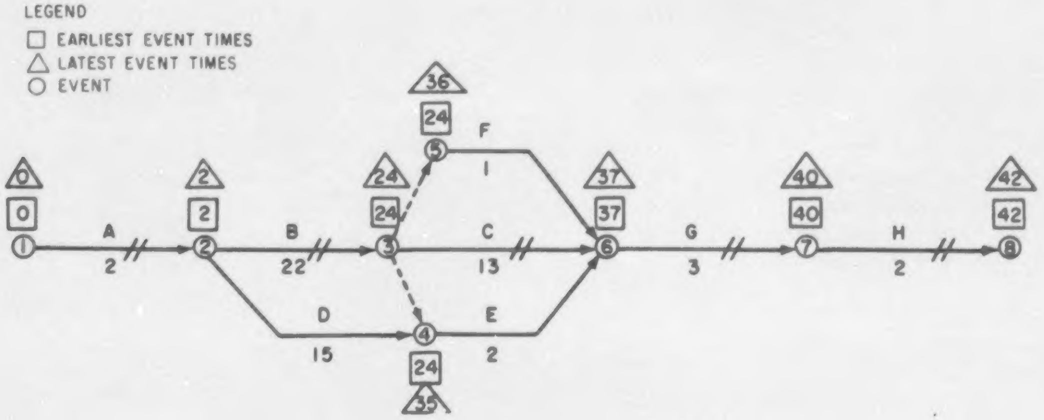

LEGEND
☐ EARLIEST EVENT TIMES
○ EVENT
0
1
A
2
2
2
B
22
24
3
C
13
24
5
F
1
37
6
4
D
15
24
E
2
G
3
40
7
H
2
42
8

82.106

Figure 4-24.—Earliest event times on arrow diagram.

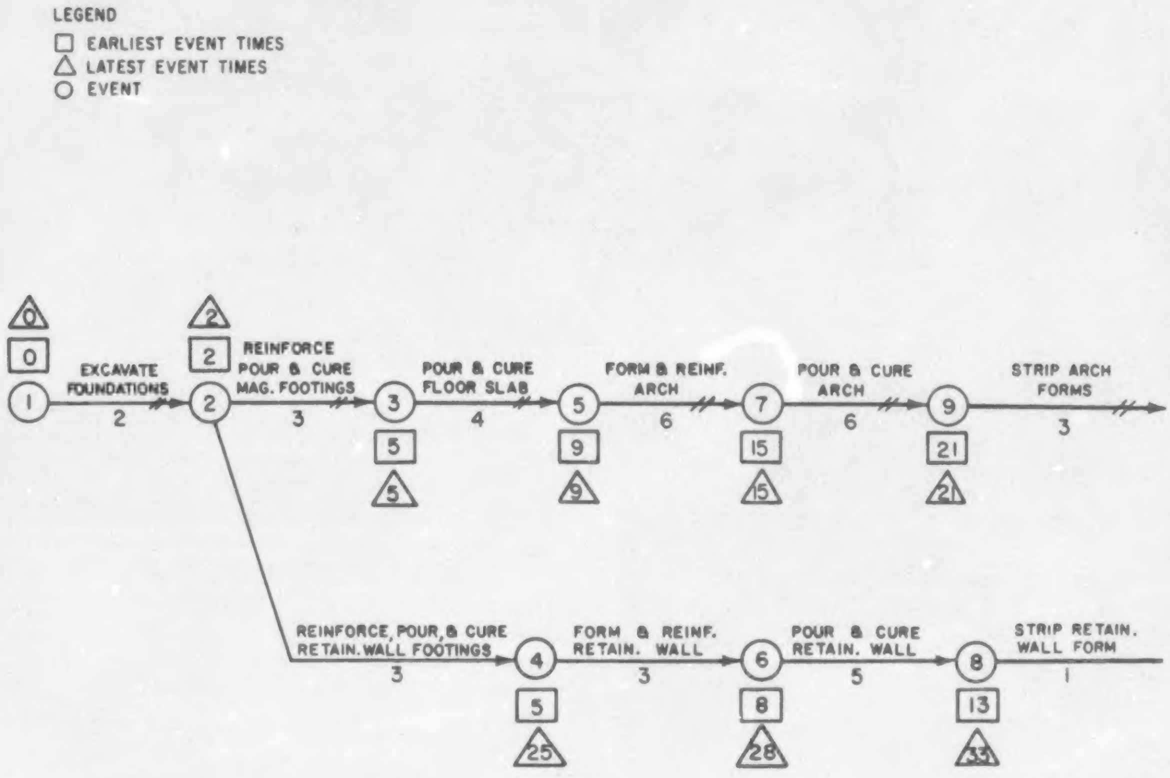
work from right to left. First, determine the latest time at which the last event can occur. This is the same as the earliest time for that event, which you already found. For example, the latest time for event (8), the last event in figure 4-25, is 42 since the earliest time for this event is 42 (See figure 4-24). Next, find the latest times at which other events on the diagram can occur. Do so for each of these events by subtracting the duration of an activity from the latest time at which the immediately following event can occur. For example, the latest time for event (7) in figure 4-25 is found by subtracting the duration of activity (7)–(8), which is 2, from the latest time of event (8), which is 42, to get 40. Likewise, the latest time for event (6) is 40-3 or 37.

To continue, the latest time for event (5) equals the latest time for event (6) minus the duration of activity (5)–(6). The result is 37-1 or 36. You find the latest time for event (4) in the same way, except that the duration of


LEGEND
☐ EARLIEST EVENT TIMES
△ LATEST EVENT TIMES
○ EVENT
0
0
1
A
2
2
2
2
B
22
24
24
3
C
13
36
24
5
F
1
37
37
6
4
D
15
24
35
E
2
G
3
40
40
7
H
2
42
42
8

82.107

Figure 4-25.—Latest event times on arrow diagram.


LEGEND
☐ EARLIEST EVENT TIMES
△ LATEST EVENT TIMES
○ EVENT
EXCAVATE FOUNDATIONS
2
REINFORCE POUR & CURE MAG. FOOTINGS
3
POUR & CURE FLOOR SLAB
4
FORM & REINF. ARCH
6
POUR & CURE ARCH
6
STRIP ARCH FORMS
3
REINFORCE, POUR, & CURE RETAIN. WALL FOOTINGS
3
FORM & REINF. RETAIN. WALL
3
POUR & CURE RETAIN. WALL
5
STRIP RETAIN. WALL FORM
1
1 2 3 4 5 6 7 8 9
0 0
2 2
5 5
9 9
15 15
21 21
5 25
8 28
13 33

activity (4)–(6) is subtracted from the latest time of event (6). In this case, 37-2 or 35 is the latest time of event (4). And so on for events (2) and (1).

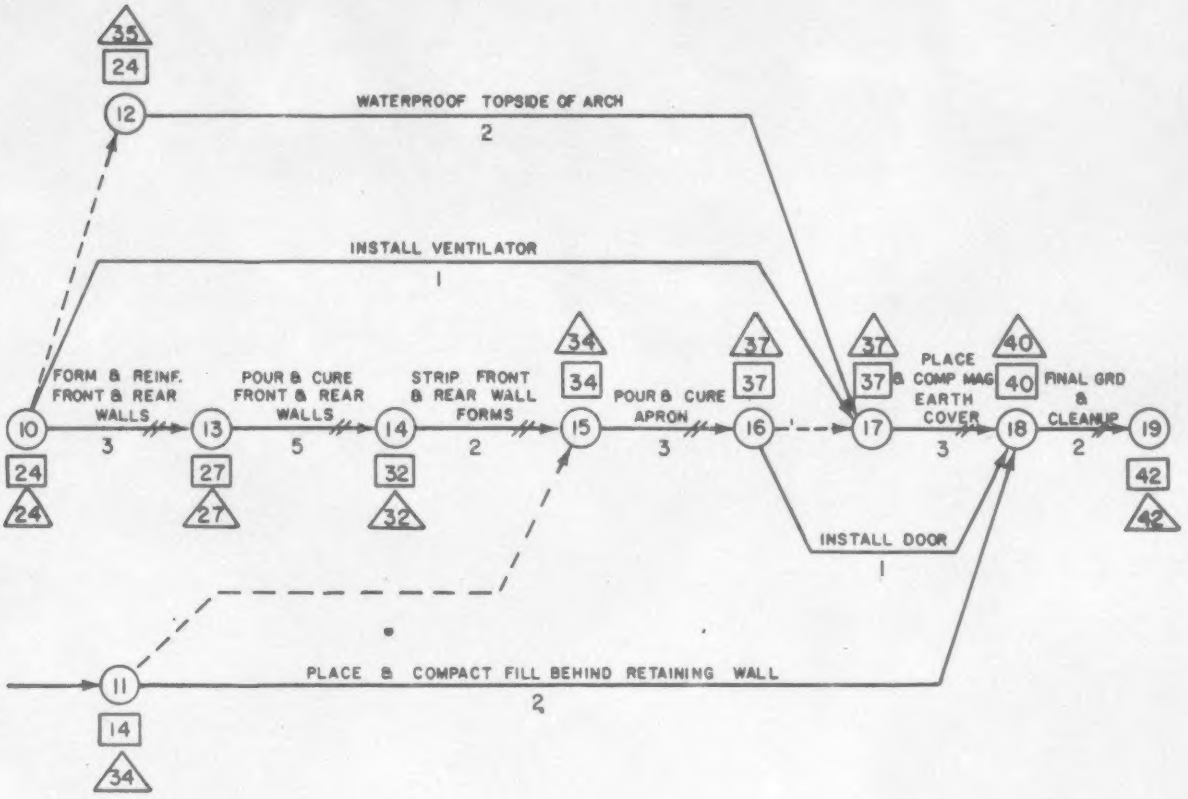
Note that for an activity on the critical path the earliest event time and the latest event time are the same; it is only for activities not on the critical path that these event times differ. It follows that identical earliest and latest event times are another means of identifying activities on the critical path.

EARLIEST AND LATEST JOB START AND FINISH TIMES

Figure 4-26 shows a fully developed arrow diagram for the project of building an arch-type magazine with all activities included, with earliest and latest event times inscribed. With earliest and latest event times established, earliest and latest starts and finishes for activities can be determined.

In figure 4-26 for example, what are the latest and the earliest days on which waterproofing of the topside of the arch can be started? What are the earliest and latest days on which the installation of the ventilator can be started?

Before either of these jobs can begin, the stripping of the arch forms, which is activity (9)–(10), must be completed. This activity is on the critical path, and it will be completed at project time 24. The waterproofing of the arch


35
24
12
WATERPROOF TOPSIDE OF ARCH
2
INSTALL VENTILATOR
1
FORM & REINF. FRONT & REAR WALLS
3
POUR & CURE FRONT & REAR WALLS
5
STRIP FRONT & REAR WALL FORMS
2
POUR & CURE APRON
3
PLACE & COMP MAG EARTH COVER
3
FINAL GRD & CLEANUP
2
INSTALL DOOR
1
PLACE & COMPACT FILL BEHIND RETAINING WALL
2
10
24
24
13
27
27
14
32
32
15
34
34
16
37
37
17
37
37
18
40
40
19
42
42
11
14
34

82.108.1

Figure 4-26.–Diagram for high-explosive magazine.

and the installation of the ventilator must be completed by project time 37, if the project is not to be delayed.

The waterproofing is a 2-day job. It can begin as early as day 25 (day of completion of stripping of arch forms plus 1), or as late as day 36 (final deadline for completion minus 2 plus 1). It can be completed as early as day 26 or as late as day 37. Similarly, the installation of the ventilator can begin as early as day 25 or as late as day 37, and can end as early as day 25 or as late as day 37.

The rules for calculating start and finish days for an activity, then are as follows:

Earliest start day: earliest event time at the tail of the arrow plus 1.

Earliest finish day: earliest start time plus job duration.

Latest start day: latest event time at the head of the arrow minus job duration plus 1.

Latest finish day: latest event time at the head of the arrow.

To calculate earliest finish days, you work from left to right on the diagram, adding job durations to earliest event times. To calculate latest start times, you work from right to left, subtracting job duration from preceding latest event time.

Results are entered in a schedule as shown in figure 4-27. This schedule assumes that all jobs will be started as early as possible.

JOB	PROJECT DAY				REMARKS
	START		FINISH		
	EARLIEST	LATEST	EARLIEST	LATEST	
(1, 2)	1	1	2	2	critical
(2, 3)	3	3	5	5	critical
(2, 4)	3	23	5	25	
(3, 5)	6	6	9	9	critical
(4, 6)	6	26	8	28	
(5, 7)	10	10	15	15	critical
(6, 8)	9	29	13	33	
(7, 9)	16	16	21	21	critical
(8, 11)	14	34	14	34	
(9, 10)	22	22	24	24	critical
(10, 13)	25	25	27	27	critical
(10, 17)	25	37	25	37	
(11, 18)	15	39	16	40	
(12, 17)	25	36	26	37	
(13, 14)	28	28	32	32	critical
(14, 15)	33	33	34	34	critical
(15, 16)	35	35	37	37	critical
(16, 18)	38	40	38	40	
(17, 18)	38	38	40	40	critical
(18, 19)	41	41	42	42	critical

82.109

Figure 4-27.—Project schedule for arrow diagram shown in figure 4-26.

CONCEPT OF SLACK

The spare time available to perform a task such as the installation of a ventilator, is called slack. Properly controlled, the manipulation of slack is valuable in determining the most efficient use of manpower, equipment, and materials. The existence of slack allows latitude in the time of the jobs with which it is associated. On the other hand, a job having no slack is inflexible; it must start and end precisely at specific times, or the completion of the project will be affected.

Rule for Calculating Slack

In figure 4-26, the task of installing the ventilator has 12 days of slack, because it is a 1-day job and there are 13 days available in which it may be performed. Similarly, the waterproofing task in the same figure has 11 days of slack. To calculate slack, subtract both the duration and the earliest event time at the tail of the arrow from the latest event time at the head of the arrow. For activity (6)–(8), for example, the slack comes to 33–8–5, or 20.

Each of the noncritical activities along the path from event (2) to event (11) has 20 days of slack when considered independently. However, there are only 20 days of slack available for the whole chain, calculated as follows: 34–2–(3 + 3 + 5 + 1) = 34–2–12 = 20.

The reason that when slack is calculated independently for each separate activity, it is assumed that all the preceding activities were started as early as possible. However, as soon as any slack is used, the slack available to subsequent activities is correspondingly reduced.

Suppose, for example, that activity (4)–(6) was delayed for 3 days. The succeeding activity (6)–(8) would have 3 days added to its earliest event time and subtracted from its slack. The slack for activity (6)–(8) would then be 33–11–5, or 17.

Use of Slack in Allocation of Manpower and Equipment

In the construction of the high-explosives magazine diagrammed in figure 4-26 there are three jobs of form stripping to be done. The stripping of the arch is critical, and must be performed between project times 21 and 24. Similarly, the stripping of the front and rear wall forms must be done between day 32 and day 34. However, the stripping of the retaining wall forms is a 1-day job which may be done at any time between project time 13 and project time 34. Obviously, the crew should be scheduled to strip the retaining wall at a time when they are not busy with the arch or front and rear wall forms. Similarly, the pouring and curing should be scheduled so as to take advantage of the slack in activity (6)–(8). By starting activity (6)–(8) one day after its earliest start time, it can be performed concurrently with activity (5)–(7). Thus, by using up a day of slack, more efficient use is made of crew and equipment.

Adjustment of Slack

Earliest and latest event times shown in the arrow diagram (fig. 4-26) were changed to reflect the days dropped out as a result of weekend curing. A check was then made to insure that the critical path was still the same, since shortening the original critical path might cause another to take its place. Next, the slack was recalculated, and the new slack values were entered in the timetable (fig. 4-28). Notice that on the timetable activity (11)–(18) and activity (17)–(18), both of which consist of placing and compacting fill (see fig. 4-26), are scheduled about a month apart. Since activity (11)–(18) shows 20 days of slack, however, and since the same equipment will be used for both activities, activity (11)–(18) should be scheduled to end the day before the critical activity (17)–(18) begins.

PREPARING A TIMETABLE

After the arrow diagram has been completed and the slack has been calculated, a timetable like the one shown in figure 4-28 can be prepared. This is a timetable derived from the arrow diagram shown in figure 4-26. Obviously, project day 1 falls on 1 March, a Thursday. No work is done on Saturdays or Sundays; therefore, though project days 1 and 2 fall on Thursday and Friday, 1 and 2 March, project day 3 falls on Monday, 5 March. As you can see, however, Saturdays and Sundays are included in the calendar when they can be utilized as curing time for concrete jobs. When this is done, such a Saturday or Sunday becomes a project day, and if the day relates to a job on the critical path, the effect is to gain time by cutting a day from the schedule. In figure 4-28, 5 days were cut from the critical path by scheduling concrete work so that curing could occur on weekends.

For example: activity (3)–(5) consisted of placing and curing the magazine footings. It was started on Thursday, so that curing could be scheduled for Saturday and Sunday. Since this job was on the critical path, the use of Saturday and Sunday for curing cut 2 days from the schedule.

MONITORING AND CONTROL

The arrow diagram produced at the beginning of a project should never be considered as fixed for the duration of the project. If the full benefit of the critical-path method is to be realized, the diagram must be updated regularly in accordance with circumstances, generally weekly or every other week, but even oftener than weekly for high-priority, complex projects.

A feedback system must be established to provide the Operations Officer with changed information about current job progress. As a project proceeds, it may be discovered that the original estimates of the times required to complete activities were not accurate or that deliveries cannot be made on time, or that

JOB	PROJECT DAYS		CALENDAR DAYS		SLACK
	START	DURATION	START	FINISH	
(1, 2)	1	2	March 1, Thurs.	March 2, Fri.	0
(2, 3)	3	3	March 5, Mon.	March 7, Wed.	0
(2, 4)	3	3	March 5, Mon.	March 7, Wed.	16[2]
(3, 5)[1]	6	4	March 8, Thurs.	March 11, Sun.	0
(4, 6)	6	3	March 8, Thurs.	March 12, Mon.	16[2]
(5, 7)	10	6	March 12, Mon.	March 19, Mon.	0
(6, 8)	9	5	March 13, Tues.	March 17, Sat.	16[2]
(7, 9)	16	6	March 20, Tues.	March 25, Sun.	0
(8, 11)	14	1	March 19, Mon.	March 19, Mon.	16[2]
(9, 10)	22	3	March 26, Mon.	March 28, Wed.	0
(10, 12)	–	0	–	–	0
(10, 13)	25	3	March 29, Thurs.	April 2, Mon.	0
(10, 17)	25	1	March 29, Thurs.	March 29, Thurs.	11[2]
(11, 15)	–	0	–	–	0
(11, 18)	15	2	March 20, Tues.	March 21, Wed.	20[2]
(12, 17)	25	2	March 29, Thurs.	March 30, Fri.	10[2]
(13, 14)[1]	28	5	April 3, Tues.	April 7, Sat.	0
(14, 15)	33	2	April 9, Mon.	April 10, Tues.	0
(15, 16)	35	3	April 11, Wed.	April 13, Fri.	0
(16, 18)	38	1	April 16, Mon.	April 16, Mon.	2
(17, 18)	38	3	April 16, Mon.	April 18, Wed.	0
(18, 19)	41	2	April 19, Thurs.	April 20, Fri.	0

[1] Curring scheduled for weekend.

[2] Adjusted to reflect weekend curing.

82.110

Figure 4-28.—Timetable from arrow diagram shown in figure 4-26.

anticipated manpower will not be available. Correction of the arrow diagram to reflect the true picture will induce changes, such as changes in completion date, critical path, intermediate target dates, slack for non-critical activities, and critical manpower or equipment schedules.

Occasionally, there may be design changes which may lead to the addition of new activities, the cancellation of previously planned activities, or the necessity for making a more detailed breakdown of work elements on the arrow diagram. Such changes may result in a shift of the critical path, or in new target dates; or they may make it necessary for certain parts of the project to be expedited in order to keep on schedule.

Crew leaders should report regularly on current work in progress. A WORK PROGRESS REPORT should include:

The completion date of each activity
The beginning date of each activity
Significant delays in current activities
Estimated number of man-days required to complete current activities.

This information enables the Operations Officer to spot trouble areas immediately and to take corrective action. A suggested work progress report is shown in figure 4-29.

RESOURCES ALLOCATION

Until now, it has been assumed that whatever personnel, materials, and equipment were required would be available to perform an activity in the allotted time. In practice, this is seldom the case, and it is often necessary to plan for the best allocation of a resource which is in short supply. An example of such resource is manpower.

One person is often not qualified to do another's job–or, at least, a person not qualified to do another's job will do it less efficiently than the fully qualified person. Therefore, manpower must be considered in terms of the qualifications or ratings of available personnel. As an example, take the erection of a temporary steel and timber warehouse. The arrow diagram for this job is shown in figure 4-30. For the sake of

PROJECT STATUS REPORT

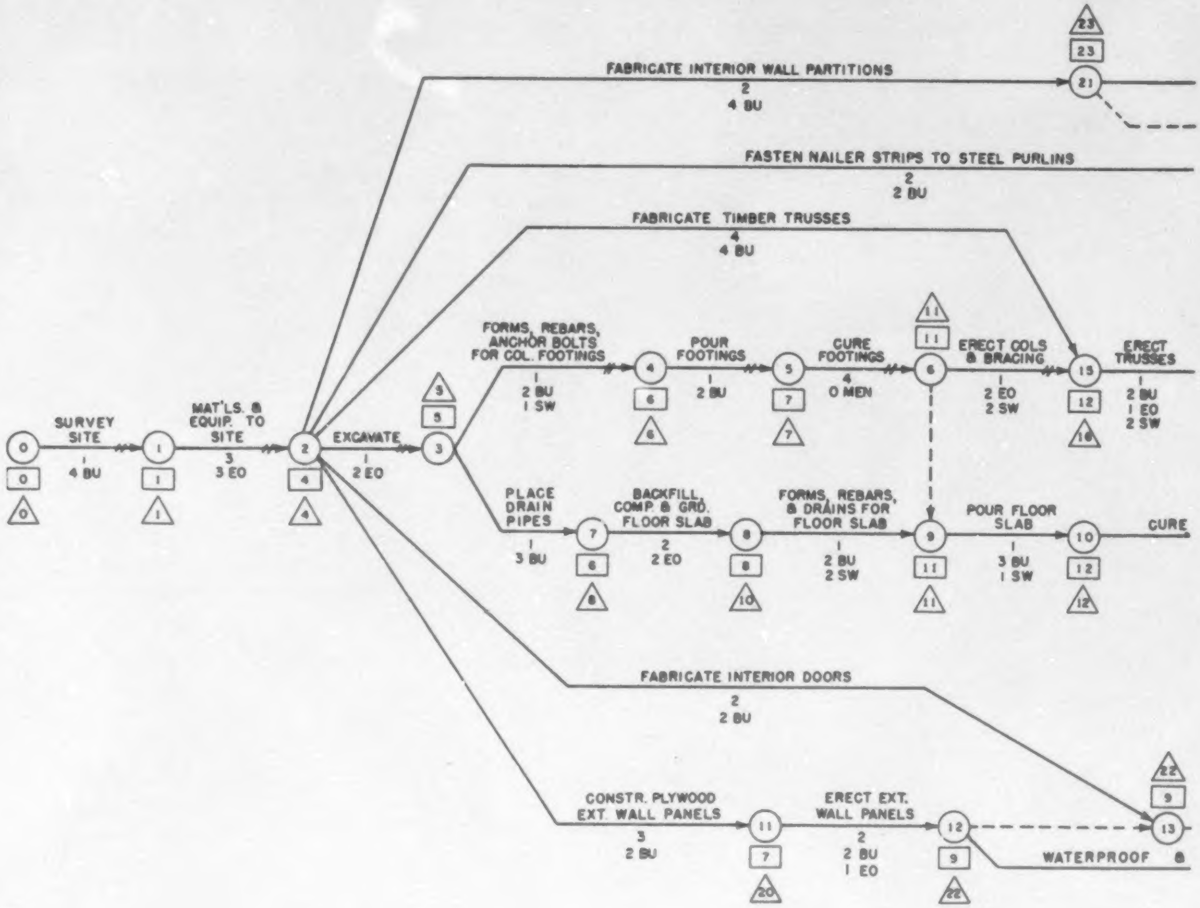
ACTIV-ITY (I, J)	BRIEF DESCRIPTION	DURA-TION	SCH. STAR.	ACT. STAR.	SCH. COMP.	TIME TO DATE	TIME REQ. TO COMP.	REMARKS

REPORT DATE ____________

SHEET ______ OF ______

82.111

Figure 4-29.—Suggested work progress report form.

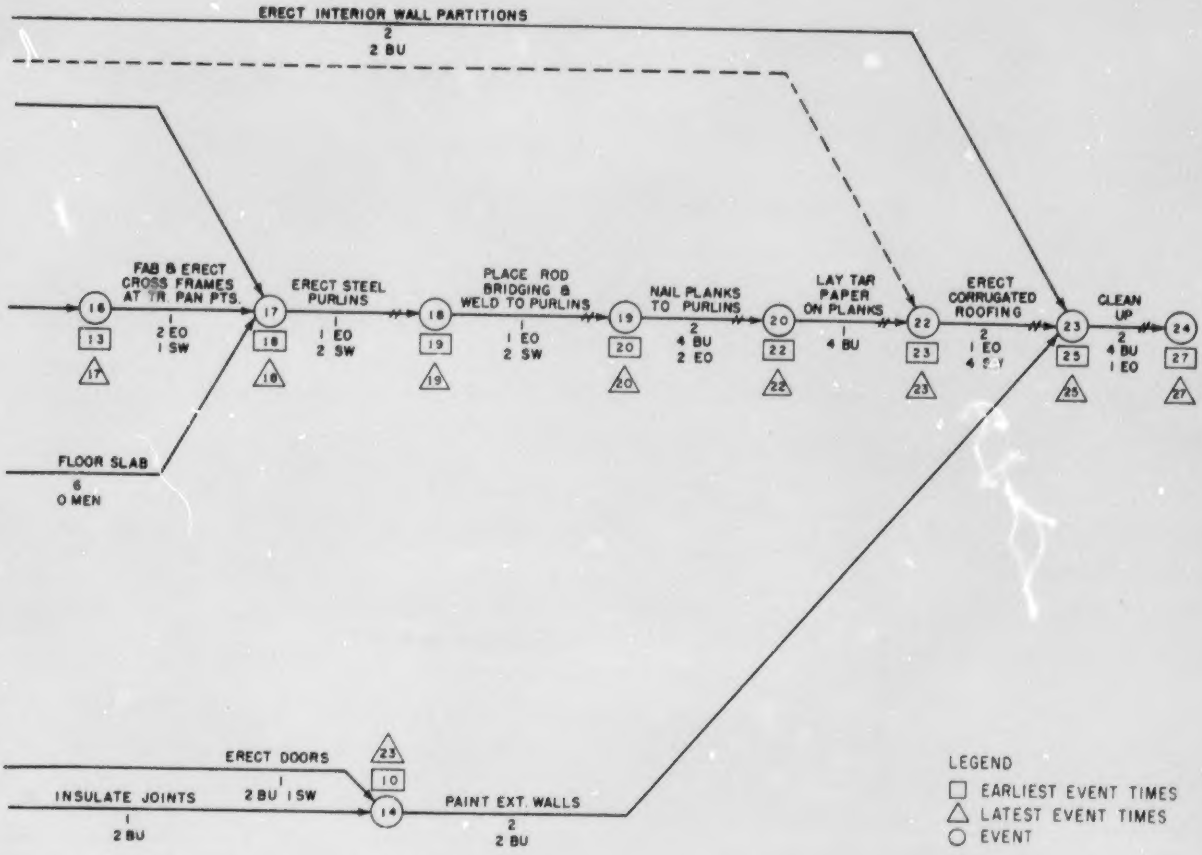

FABRICATE INTERIOR WALL PARTITIONS
2
4 BU
23
23
21
FASTEN NAILER STRIPS TO STEEL PURLINS
2
2 BU
FABRICATE TIMBER TRUSSES
4
4 BU
FORMS, REBARS, ANCHOR BOLTS FOR COL. FOOTINGS
1
2 BU
1 SW
POUR FOOTINGS
1
2 BU
CURE FOOTINGS
4
0 MEN
11
11
ERECT COLS & BRACING
1
2 EO
2 SW
ERECT TRUSSES
1
2 BU
1 EO
2 SW
SURVEY SITE
1
4 BU
MAT'LS. & EQUIP. TO SITE
3
3 EO
EXCAVATE
1
2 EO
0
0
0
1
1
1
2
4
4
3
5
3
4
6
6
5
7
7
6
15
12
16
PLACE DRAIN PIPES
1
3 BU
BACKFILL, COMP. & GRD. FLOOR SLAB
2
2 EO
FORMS, REBARS, & DRAINS FOR FLOOR SLAB
1
2 BU
2 SW
POUR FLOOR SLAB
1
3 BU
1 SW
CURE
7
6
8
8
8
10
9
11
11
10
12
12
FABRICATE INTERIOR DOORS
2
2 BU
22
9
13
CONSTR. PLYWOOD EXT. WALL PANELS
3
2 BU
ERECT EXT. WALL PANELS
2
2 BU
1 EO
WATERPROOF &
11
7
20
12
9
22

simplicity, it is assumed that only Builders, Equipment Operators, and Steelworkers will be used on the job.

There must be some sort of schedule as a point of departure. Referring to the arrow diagram, you list all of the activities in the order in which they can begin, as shown in figure 4-31. When several activities can begin on the same day, list them secondarily in order of the amount of slack they contain. If two or more activities have the same amount of slack and start on the same day, it doesn't matter which is placed first. The easiest way to arrange the activities in order for copying on the schedule is to list each activity on a 3 x 5 card and sort the cards into proper order.

Next you transfer the values shown in this preliminary schedule to a bar chart like the one shown in figure 4-32. The broken lines indicate slack. The bar graph is a schedule for the project, but based on the assumption that available manpower is unlimited.

At this point, or previously, you enter on the arrow diagram the manpower requirements


ERECT INTERIOR WALL PARTITIONS
2
2 BU
FAB & ERECT CROSS FRAMES AT TR. PAN PTS.
1
2 EO
1 SW
ERECT STEEL PURLINS
1
1 EO
2 SW
PLACE ROD BRIDGING & WELD TO PURLINS
1
1 EO
2 SW
NAIL PLANKS TO PURLINS
2
4 BU
2 EO
LAY TAR PAPER ON PLANKS
1
4 BU
ERECT CORRUGATED ROOFING
2
1 EO
4 SW
CLEAN UP
2
4 BU
1 EO
16
13
17
17
18
18
19
19
20
20
22
22
23
23
23
25
25
24
27
27
FLOOR SLAB
6
0 MEN
ERECT DOORS
1
2 BU 1 SW
INSULATE JOINTS
1
2 BU
23
10
14
PAINT EXT. WALLS
2
2 BU
LEGEND
□ EARLIEST EVENT TIMES
△ LATEST EVENT TIMES
○ EVENT

82.112

Figure 4-30.—Arrow diagram-temporary steel and timber warehouse.

shown already entered in figure 4-33. These are, of course, based on estimates of how many persons of each rating it will take to do each of the activities shown in the diagram. By referring to these figures and to the bar chart (fig. 4-32) you can now make a manpower schedule as shown in figure 4-33.

Examination of the manpower totals in figure 4-33 shows undesirable peaks in the Builder requirements–14 called for on day 5, 19 on day 6, 8 on day 7, and so on. To correct this situation, you would decide what the maximum available number of Builders would be for a day, and rework the chart on the basis of this limitation. The general procedure is as follows:

1. List all activities in the same order as before (fig. 4-30).

2. Enter the critical activities in the same places as before; these cannot be displaced.

3. Use slack time on non-critical activites to shift activities using Builders to days on which, on the previous chart, Builders were not shown employed. For example: activity (2)–(15) in

EARLIEST EVENT AT TAIL OF ARROW	ACTIVITY (I, J)	DURATION	LATEST EVENT AT HEAD OF ARROW	SLACK
0	(0, 1)	1	1	0
1	(1, 2)	3	4	0
4	(2, 3)	1	5	0
4	(2, 15)	4	16	8
4	(2, 17)	2	18	12
4	(2, 11)	3	20	13
4	(2, 13)	2	22	16
4	(2, 22)	2	24	18
5	(3, 4)	1	6	0
5	(3, 7)	1	8	2
6	(4, 5)	1	7	0
6	(7, 8)	2	10	2
7	(5, 6)	4	11	0
7	(11, 12)	2	22	13
8	(8, 9)	1	11	2
9	(12, 13)	0	22	13
9	(12, 14)	1	23	13
9	(13, 14)	1	23	13
10	(14, 23)	2	25	13
11	(6, 9)	0	11	0
11	(9, 10)	1	12	0
11	(6, 15)	1	16	4
12	(10, 17)	6	18	0
12	(15, 16)	1	17	4
13	(16, 17)	1	18	4
18	(17, 18)	1	19	0
19	(18, 19)	1	20	0
20	(19, 20)	2	22	0
22	(20, 21)	1	23	0
23	(21, 23)	2	25	0
23	(21, 22)	0	24	1
23	(22, 23)	1	25	1
25	(23, 24)	2	27	0

82.113

Figure 4-31.—List of activities in figure 4-30, in order of earliest events (tail of arrows).

figure 4-33 could be shifted to days 13 through 16, since the chart shows only 2 Builders working on day 13 and none on days 14, 15, and 16.

4. After every adjustment of this kind, refer back to the arrow diagram and the schedule, to see whether in rescheduling activities you have moved back the times at which subsequent activities can start.

In practice, it is often possible to split work elements—to do part of the work on the fabrication of doors (for example) on one day, then drop this and pick it up at a later day when Builders are available.

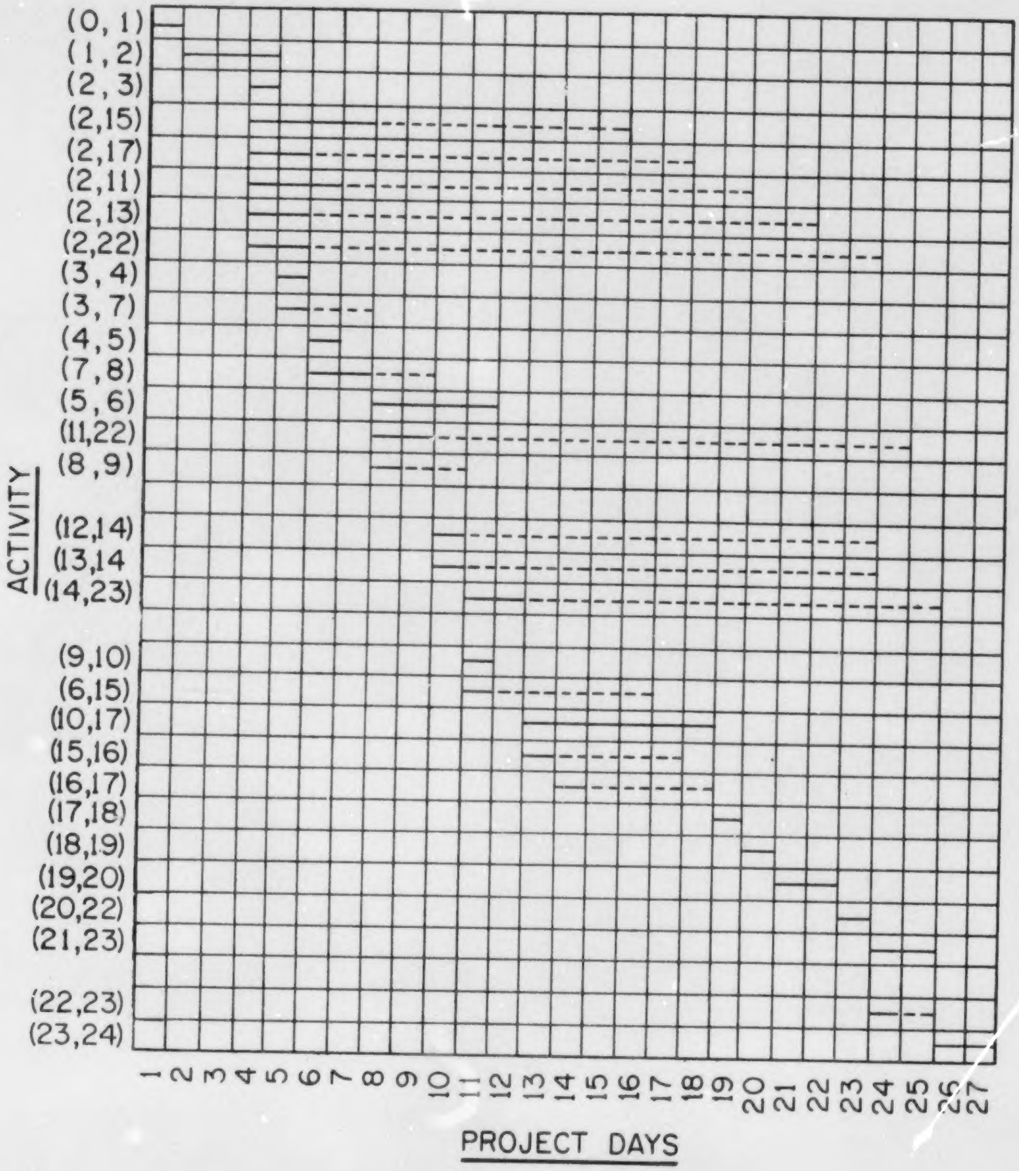


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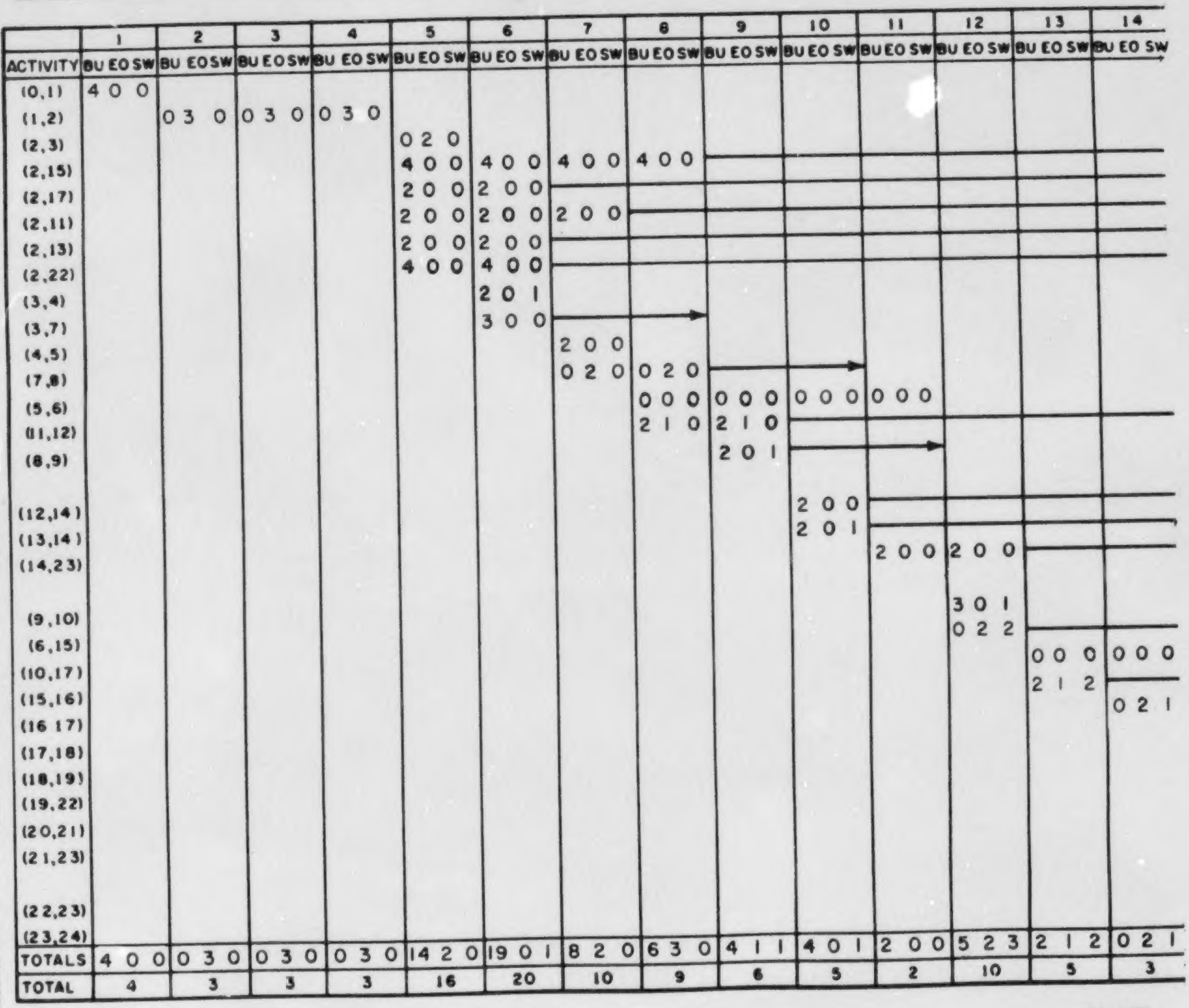
Figure 4-32.—Bar chart—preliminary schedule of activities listed in figure 4-31.

Remember that, when you make this or any other type of adjustment, you must immediately check the arrow diagram for the effect on subsequent activities. On even a small project, the possibility for improving efficiency through adjustments in scheduling or through job splitting nearly always exists—or, at any rate, exists until the most efficient schedule is found. Because of the interrelationship between work elements and the effect they have on each other,



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ACTIVITY	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW
(0,1)	4 0 0													
(1,2)		0 3 0	0 3 0	0 3 0										
(2,3)					0 2 0									
(2,15)					4 0 0	4 0 0	4 0 0	4 0 0						
(2,17)					2 0 0	2 0 0								
(2,11)					2 0 0	2 0 0	2 0 0							
(2,13)					2 0 0	2 0 0								
(2,22)					4 0 0	4 0 0								
(3,4)						2 0 1								
(3,7)						3 0 0								
(4,5)							2 0 0							
(7,8)							0 2 0	0 2 0						
(5,6)								0 0 0	0 0 0	0 0 0	0 0 0			
(11,12)								2 1 0	2 1 0					
(8,9)									2 0 1					
(12,14)										2 0 0				
(13,14)										2 0 1				
(14,23)											2 0 0	2 0 0		
(9,10)												3 0 1		
(6,15)												0 2 2		
(10,17)													0 0 0	0 0 0
(15,16)													2 1 2	
(16 17)														0 2 1
(17,18)														
(18,19)														
(19,22)														
(20,21)														
(21,23)														
(22,23)														
(23,24)														
TOTALS	4 0 0	0 3 0	0 3 0	0 3 0	14 2 0	19 0 1	8 2 0	6 3 0	4 1 1	4 0 1	2 0 0	5 2 3	2 1 2	0 2 1
TOTAL	4	3	3	3	16	20	10	9	6	5	2	10	5	3

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Figure 4-33.—Manpower schedule—temporary timber and steel warehouse (considering three ratings).

much experimentation and readjustment may be required to attain the most efficient and economical schedule.

The schedule that stays completely accurate through the entire life of a project, as originally developed, is extremely rare. Periodic revision and refinement is a necessary and valuable part of network analysis. It is up to the network analysis user to analyze the schedule to make certain that it is meaningful and accurate, and to enforce the accomplishment of it.

Since many services, trades, and supplies are required during the course of construction, leading petty officers responsible for the various activities should be consulted. Network analysis requires a team effort on the part of all participants to make it work effectively.

EARTHWORK COMPUTATIONS

Earthwork computations are the calculations of earthwork volumes or quantities to determine

15	16	17	18	19	20	21	22	23	24	25	26	27	
BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	BU EO SW	ACTIVTY
													(0,1)
													(1,2)
													(2,3)
→	→												(2,15)
→	→	→	→										(2,17)
→	→	→	→	→	→								(2,11)
→	→	→	→	→	→	→	→						(2,13)
→	→	→	→	→	→	→	→	→	→				(2,22)
													(3,4)
													(3,7)
													(4,5)
													(7,8)
													(5,6)
→	→	→	→	→	→	→	→						(11,12)
													(8,9)
→	→	→	→	→	→	→	→	→					(12,14)
→	→	→	→	→	→	→	→	→					(13,14)
—	—	—	—	—	—	—	—	—	—	—			(14,23)
													(9,10)
→	→												(6,15)
0 0 0	0 0 0	0 0 0	0 0 0										(10,17)
→	→	→											(15,16)
→	→	→	→										(16,17)
				0 1 2									(17,18)
					0 1 2								(18,19)
						4 2 0	4 2 0						(19,20)
								4 0 0					(20,22)
									0 1 4	0 1 4			(21,23)
									2 0 0	→			(22,23)
											4 1 0	4 1 0	(23,24)
0 0 0	0 0 0	0 0 0	0 0 0	0 1 2	0 1 2	4 2 0	4 2 0	4 0 0	2 1 4	0 1 4	4 1 0	4 1 0	TOTALS
0	0	0	0	3	3	6	6	4	7	5	5	5	TOTAL

82.115

Figure 4-33.—Manpower schedule—temporary timber and steel warehouse (considering three ratings)—Continued.

final grades, to balance cut and fill, and to PLAN the most economical haul of material. Materials to be imported and mixed with subgrade soils for subgrade stabilization are included in earthwork computations, but base course or paving materials to be placed above the subgrade are not included. Where topsoil or unsuitable material is stripped from cut and fill areas and placed outside the slope stake limits, cut and fill quantities affected must be corrected to compensate for the loss of the material.

The precision of earthwork computations is dependent upon the extensiveness of field measurements (closeness of cross sections, amount of details located, and so on) during the survey. The extent of field measurements, in turn, must necessarily be consistent with the situation. When time is a vital element and the type of construction is low, earthwork quantities are estimated either very roughly or not at all. An example of this would be where a road is built over flat or slightly rolling ground, and excavation for ditches is merely thrown on the roadbed to form a crown. Practically no haul would be involved and earthwork computations would be unwarranted. In the case of a primary road, and for most airfield construction, deliberate earthwork computations are necessary.

CROSS SECTION METHOD

The cross section method of computing earthwork volumes is the most widely used method in both road and airfield construction.

After the position of the subgrade line and the shape of the typical cross section are established, cross sections are plotted for each 100-foot station on the adopted centerline in runway construction, for each 100-foot station on tangents, and for every 50 feet on curves in road and taxiway construction. Cross sections are also plotted at any intermediate place where there is a distinct change in slope along the centerline where the natural ground profile and the grade line correspond. This is also true where the earthwork changes from cut to fill, and where the surface on either side of the centerline is uneven enough to require plotting a section in order to represent properly the volumes indicated between the cross sections. Cross sections are plotted on cross section paper.

CALCULATIONS OF PLOTTED CROSS SECTION AREAS

There are several methods of determining the areas of a cross section, among which are the following: counting-the-squares method, strippers method, double-meridian-distance or trapezoidal method, and the planimeter method. The counting-the-squares and stripper methods give approximate results, whereas the trapezoidal and planimeter methods are more exact.

The counting-the-squares method consists of counting the squares in a cross section that has been plotted on cross section paper. Each square represents an area. The area in square feet of one square depends on the horizontal and vertical scales used in plotting the cross section. The scales are usually the same, but an exaggerated scale may be used if the vertical cut or fill is small compared to the width. The sum of the squares equal the area of the cross section.

To simplify the counting the squares method, you can draw a rectangle as shown by the dash lines of the cross section in figure 4-34, then multiplying, in this case, 3 by 20 = 60 squares; then count the remaining squares between each of the heavy black lines. In square "a" you have approximately 13 squares; in the large square "b" there are 5 squares; in square "c" there are approximately 4 squares (combining all the small areas along the upper ground line); and in square "d" there are approximately 9 squares, giving you a total of 91 squares. Since each square represents one square foot in this case, the end area is 91 square feet.

AVERAGE END AREA METHOD OF COMPUTING VOLUMES

The average end area method is commonly used to determine the volume between two trapezoidal cross sections or end areas. The following formula applies:

$$V = \frac{L(A_1 + A_2)}{54}$$

in which V is the volume in cubic yards of the prismoid between cross sections having areas in square feet of A_1 and A_2 separated by a distance L, in feet. If cross sections are taken at full 100-foot stations, the volume in cubic yards

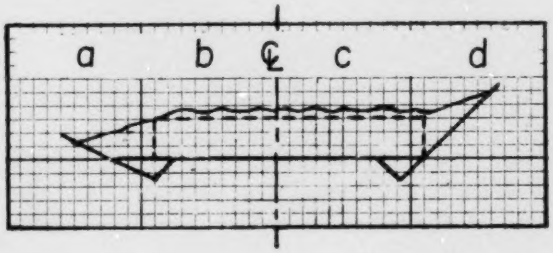

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Figure 4-34.—Counting the squares in a cross section.

between successive cross sections A_1 and A_2, may be found directly by the simplified formula:

$$V = 1.85\ (A_1 + A_2)$$

In either form, the formula is accurate only when A_1 and A_2 are approximately of the same shape. The greater the difference in shape between the two end sections, the greater the error, and an error as great as 50 percent can occur. Although the results obtained by this method of earthwork computation are approximate, it is consistent with field methods in general use. In most cases, a more accurate method is not justified.

Now apply the formula to a sample case. Assume that cross section A_1 is at station 1 + 00 and has an area of 182 square feet. Assume further that the cross sectional area at station 2 + 00 is 190 square feet. In applying the simplified formula, you get V = 1.85 (182 + 190). This results in 1.85 x 372 or 688 cubic yards of material between stations 1 + 00 and 2 + 00.

To apply the formula for other than 100-foot stations, assume that the distance between A_1 and A_2 is 75 feet and that the cross sectional area of A_2 at station 1 + 75 is 198 square feet.

$$V = \frac{L\ (A_1 + A_2)}{54} = \frac{75\ (182 + 198)}{54} =$$

$$\frac{75 \times 380}{54} = 528 \text{ cubic yards}$$

THE PRISMOIDAL FORMULA

When there is a need for a more precise volume computation than can be obtained with the average end area method, the prismoidal formula is commonly used:

$$V = \frac{L\ (A_1 + 4A_m + A_2)}{162}$$

The letters V, L, A_1, and A_2 have the same meaning as in the previous formulas, but A_m is the area (in square feet) of the cross section halfway between A_1 and A_2 as shown in figure 4-35. Note the A_m is not the average of A_1 and A_2. Instead, the elevations and distances from the centerline in A_m are the averages of comparable values in A_1 and A_2. For example, at the left slope stake, the distance 16.1 is halfway between 15.2 and 17.0, and the elevation 70.7 is halfway between 70.2 and 71.2. The area of A_m is determined in the usual manner. Using the values in figure 4-35, the volume is computed as follows:

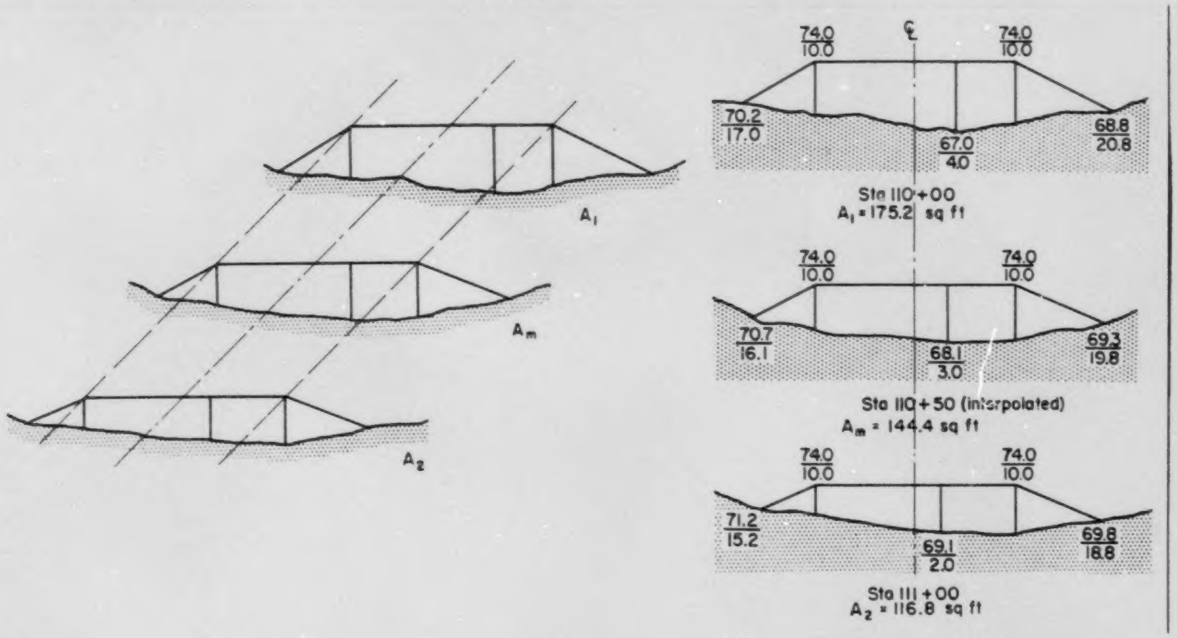
$$V = \frac{100\ (175.2 + (4 \times 144.4) + 116.8)}{162}$$

$$= 537 \text{ cubic yards}$$

MASS DIAGRAM METHOD

The mass diagram is a graph or curve on which the algebraic sums of cuts and fills are plotted against linear distance. Before these cuts and fills are tabulated, the swells and compaction factors are considered in computing the yardage. Earthwork that is in-place will yield more yardage when excavated and less yardage when being compacted. An example of this is sand: 100 cubic yards in-place yields 111 cubic yards loose and only 95 cubic yards when compacted. These factors should be used when preparing a table of "cumulative yardage" for a mass diagram. Cuts are indicated by a rise in the curve, and are considered positive; fills are indicated by a drop in the curve, and are considered negative. The yardage between any pair of stations can be determined by inspection. This feature makes the mass diagram a great help in the attempt to balance cuts and fills within the limits of economic haul.

The limit of economic haul is reached when the cost of haul and the cost of excavation become equal. Beyond that point it is cheaper to waste the cut from one place, and to fill the adjacent hollow with material taken from a nearer borrow pit. The limit of economic haul will, of course, vary at different stations on the project, depending on the nature of the terrain,


A₁
A_m
A₂
74.0/10.0
℄
74.0/10.0
70.2/17.0
67.0/4.0
68.8/20.8
Sta 110+00
A₁ = 175.2 sq ft
74.0/10.0
74.0/10.0
70.7/16.1
68.1/3.0
69.3/19.8
Sta 110+50 (interpolated)
A_m = 144.4 sq ft
74.0/10.0
74.0/10.0
71.2/15.2
69.1/2.0
69.8/18.8
Sta 111+00
A₂ = 116.8 sq ft

143.111

Figure 4-35.—Areas for use in the prismoidal formula.

availability of equipment, type of material, accessibility, availability of manpower, and other considerations.

There exists what is called a FREE-HAUL distance—that is, a distance over which it is considered that haul involves no extra cost. This distance is usually taken to be about 500 ft—meaning that it is only for hauls longer than 500 ft that the limits of economic haul need to be considered.

TABULATING CUMULATIVE YARDAGE

The first step in making a mass diagram is to prepare a table of cumulative yardage like the one shown in table 4-1. Under "End Areas" you put the cross section area at each station—sometimes this is cut, sometimes fill, and sometimes (as at station 9 + 00 and 15 + 00) part cut and part fill. Under "Volumes" you put the volumes of cut and/or fill between stations, computed from the average end areas and the distance between sections, in cubic yards. Note that, besides the sections at each full station, sections are taken at every plus where both the cut and the fill are zero. Note also that cut volumes are designated as plus, fill volumes as minus.

Under "Algebraic Sums, Volumes, Cumulative" you put the cumulative volume at each station and each plus, computed in each case by determining the algebraic sum of the volume at that station or plus and the preceding cumulative total. For example: at station 8 + 00 the cumulative total is -563. At station 9 + 00 there is a volume of cut of +65 and a volume of fill of -305, making a net of -240. The cumulative total at station 9 + 00, then, is (-563) + (-240), or -803.

PLOTTING MASS DIAGRAM

The lower half of figure 4-36 shows the values from the table of cumulative yardage plotted on a mass diagram. The vertical

Table 4-1.–Table of Cumulative Yardage

CUMULATIVE YARDAGE					
STATION	END AREAS (FT^2)		VOLUMES (YD^3)		ALGEBRAIC SUMS, VOLUMES, CUMULATIVE
	CUT	FILL	CUT	FILL	
0 + 00	186	0	---	---	0
1 + 00	65	0	+465	---	+465
2 + 00	44	0	+202	---	+667
3 + 00	22	0	+122	---	+789
3 + 50	0	0	+20	---	+809
4 + 00	0	22	---	-20	+789
5 + 00	0	44	---	-122	+667
6 + 00	0	65	---	-202	+465
7 + 00	0	186	---	-465	0
8 + 00	0	119	---	-563	-563
9 + 00	35	46	+65	-305	-803
9 + 08	0	0	+5	-7	-805
10 + 00	0	22	---	-37	-842
10 + 50	0	0	---	-20	-862
11 + 00	22	0	+20	---	-842
12 + 00	44	0	+122	---	-720
13 + 00	87	0	+242	---	-478
14 + 00	218	43	+563	-80	5
15 + 00	64	22	+521	-120	+406
15 + 07	0	0	+8	-8	+406
16 + 00	32	0	+55	---	+461
16 + 50	0	0	+30	---	+491
17 + 00	0	32	---	-30	+461
18 + 00	0	61	---	-172	+289
19 + 00	0	157	---	-405	-116
20 + 00	90	95	+166	-466	-416

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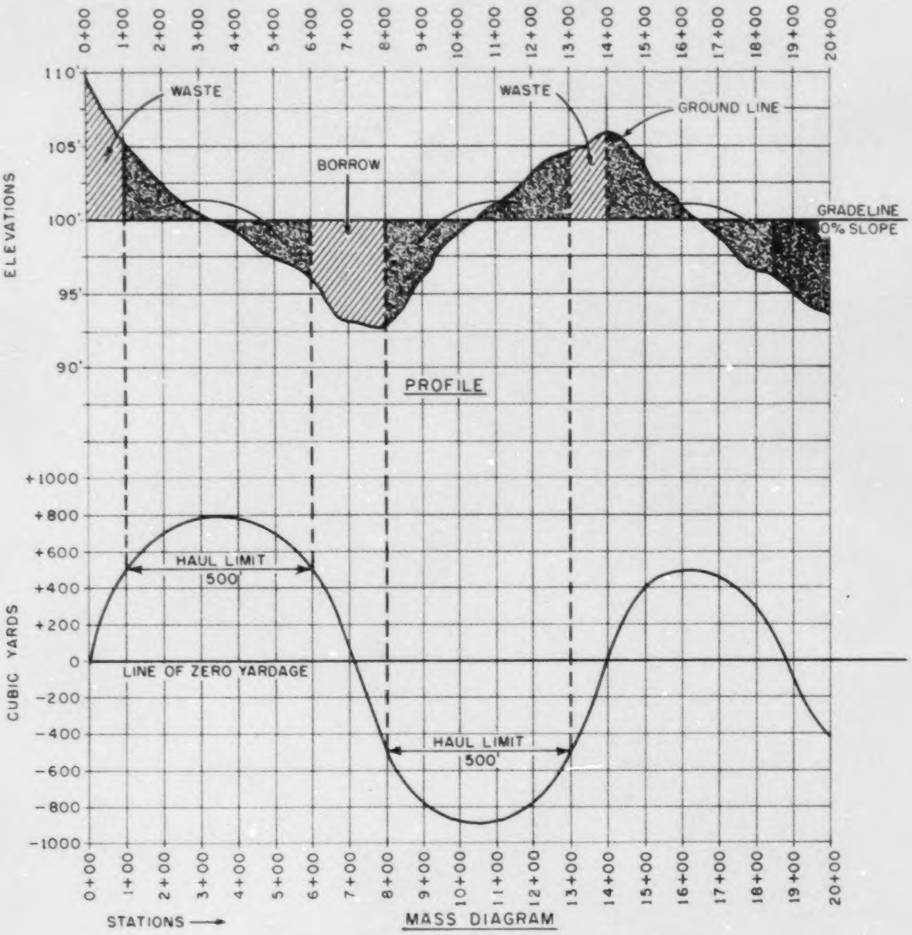

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Figure 4-36.—Profile and mass diagram.

coordinates are cumulative volumes, plus or minus from a LINE OF ZERO YARDAGE, each horizontal line representing an increment of 200 cu yd. The horizontal coordinates are the stations, each vertical line representing a full 100-ft station.

As you can see, the mass diagram makes it possible for you to determine, by inspection, the yardage of cut or fill lying between any pair of stations. Between station 0 + 00 and station 3 + 50, for example, there are about 800 cu yd of cut. Between station 3 + 50 and station 7 + 00 there are about 800 cu yd of fill (descending curve). Between station 7 + 00 and station 10 + 50 there are about 850 cu yd of fill (curve still descending), and so on.

Remember that sections where the volume (yardage) changes from cut to fill correspond to a maximum in the mass diagram curve, and sections where it changes from fill to cut correspond to a minimum. The peaks and the lowest points of the mass diagram, which represent the maximum or minimum yardage, occur at, or near, the gradeline on the profile.

BALANCING CUTS AND FILLS

To understand the manner in which the mass diagram is used to balance cuts and fills and how the haul limit is determined, examine the upper half of figure 4-36.

Here the profile of a road, stations 0 + 00 to 20 + 00, has been plotted above the mass diagram. You can see that the profile and mass diagram are plotted on the same horizontal scale. The labeled sections and arrows on the profile show relatively what is to be done to the cuts and fills, and where the limit of economical haul is exceeded, the cut is wasted, or the fill is borrowed. A 500-ft haul limit line was inserted into the mass diagram curve above and below the lines of zero yardage. The terminal points of each haul limit distance were projected to the profile curve as indicated. It is not necessary to indicate haul limits less than 500-ft as happens between stations 14 + 00 and 18 + 50. You can see that the cut lying between stations 1 + 00 and 3 + 50 can be hauled economically as far as station 6 + 00, that lying between stations 10 + 50 and 13 + 00 as far as station 8 + 00, and that lying between stations 14 + 00 and 16 + 50 as far as station 18 + 50. This leaves the cut between stations 0 + 00 and 1 + 00, the fill between stations 6 + 00 and 8 + 00, the cut between stations 13 + 00 and 14 + 00, and the fill between stations 18 + 50 and 20 + 00.

As indicated in figure 4-36 the cut between stations 0 + 00 and 1 + 00, lying outside the limit of economical haul distance, would be wasted; that is, dumped into a nearby spoil area or ravine. The cut between stations 1 + 00 and 3 + 50 would be dumped into the adjacent fill space between stations 3 + 50 and 6 + 00. The fill space between stations 6 + 00 and 8 + 00 would be filled with borrow; that is, material taken from a nearby borrow pit. The fill space between stations 8 + 00 and 10 + 50 would be filled with the cut between stations 10 + 50 and 13 + 00, and the space between stations 16 + 50 and 18 + 50 would be filled with cut lying between stations 14 + 00 and 16 + 50. The haul limit for the last section of the mass diagram (between stations 14 + 00 and 18 + 50) is almost on the line of zero yardage. This haul limit distance is also called the balance line, because the volume of cut is equal to the volume of fill. If, for example, the balance line on the last section of the mass diagram in figure 4-36 is only about 300 ft, then instead of wasting the cut between stations 13 + 00 and 14 + 00, you would use that to fill the hollow between stations 18 + 50 and 20 + 00. Surplus cut remaining would naturally be wasted after allowing for shrinkage in the filled spaces.

CHAPTER 5

GRADING, SOIL STABILIZATION, AND ROAD SURFACING

You have served as a crewmember on many construction projects and as an operator of many different types of equipment used on such operations as grading, soil stabilization, road surfacing, asphalt plants, and so on. On advancement to EO1 or EOC, your responsibilities will change from that of a crewmember or operator, to that of a planner, instructor, and supervisor. With this in mind, let's take a look at the sequence and development of general job operations of grading, soil stabilization, and road surfacing. In doing so, we will discuss proper operational techniques, and factors involving site development of materials, mixes, equipment and plant service checks, maintenance, and safety.

GRADING OPERATIONS

As a supervisor, it is your responsibility to see that grader operators use proper techniques to obtain maximum grader efficiency. Some techniques that will prove useful are discussed below.

When the grader is to make a number of passes over a distance of less than approximately 1,000 feet, it is normally more efficient to have your operators back the grader the entire distance to the starting point than to have them turn the grader around.

Efficiency of grader work is in direct proportion to the number of passes made. Operator skill, coupled with planning, is of the utmost importance in eliminating unnecessary passes. For example, if four passes will complete a job, every added pass increases the time for the job to be completed by 25 percent.

Proper tire inflation is necessary for effective grader operations. Overinflated tires mean a small contact area between the tires and the project area surface with a resulting loss of traction. Differences of pressure in rear tires cause wheel slippage and grader bucking. Correct inflation for grader tires is given in the operator's manual supplied by the manufacturer of the particular type grader being used. BE SURE THAT THE OPERATOR CHECKS THE TIRES PRIOR TO STARTING THE DAY'S WORK.

It will be your job to check the haul road, and see that it is properly maintained. When towed or motorized scrapers, dozers, or off-highway trucks are being used on a large construction project, efficiency is increased if the condition of the haul road permits high gear operation (speed). Your graders are the best machines for maintaining the haul roads. Therefore, be sure your operators have been instructed on the proper procedures, so that they don't interfere with the traffic of your other construction equipment.

The most efficient method of road maintenance is to use enough graders to complete each side of the road with one pass by each grader. In this way, one side remains open to traffic. Also, operation such as leveling, mixing, and spreading are expedited by using graders in tandem.

Construction operations are hindered by rain, but ROAD MAINTENANCE OPERATIONS often can be performed best after a rain. Where responsibility exists for maintenance of dirt or gravel roads, every effort should be made to concentrate all available grader effort during the short period following a rain when the soil is damp.

Operations are performed as fast as possible, consistent with the skill of the operator and the condition of the surface being maintained. Operation in each gear is at full throttle. If less speed is required, a lower gear should be used. Normally, if the operator is operating the grader too fast, the grader will have a tendency to bounce, thereby giving the surface a washboard appearance, which will require additional time and passes by the grader. Make sure your operators are aware of this problem. If washboarding is not corrected, it will create unnecessary wear and tear on the other construction equipment utilizing the haul road or work area. Table 5-1 lists speeds normally used in various grader operations. Make your operators aware of these speed ranges when performing various grader operations.

Skilled operators can increase the efficiency of an operation by grading in reverse when distances are long and turning impracticable. Remember: this type of operations is for skilled operators only.

Side ditches must be kept free of debris and other obstructions to avoid overflowing of the ditch during a rain, and to prevent sidehill seepage entering the roadbed or runway.

If the subgrade is to be crowned prior to final surfacing, keep an eye on the less experienced operators, as they tend to make the crown too steep. Instruct them to adjust the angle of the blade correctly before starting.

In ditching you are apt to find that inexperienced operators have a tendency to overcut (cut below the ditch bottom). This can lead to erosion problems, or it could even require considerable time to correctly replace the excess material the operator had originally removed. It is better that you instruct the operator to take a smaller cut requiring an extra pass.

Table 5-1.—Approximate Speed Ranges Used in Various Grader Operations

Operation	Speed (mph)	Operation	Speed (mph)
Maintenance	3 to 10	Bank sloping	2
Spreading	3 to 6	Snow removal	10 to 15*
Mixing	5 to 15	Finishing	3 to 5
Ditching	2 to 3		

***Exception to maximum speed permissible on high type runways and highways.**

A checklist for you, as supervisor, to use in determining the efficiency of grader performance, is given in table 5-2.

EQUIPMENT FOR GRADING

The characteristics, functions, and applicable operation, maintenance and safety procedures for the motorized grader are discussed in detail in the *Equipment Operator 3 & 2,* NAVEDTRA 10640-H.

ESTIMATING GRADER OUTPUT

The time required to complete a grader operation depends upon the number of passes necessary and the speed maintained on each pass. In turn, this speed depends largely upon the skill of the operator and the type of material handled. A work output formula which may be used to prepare preliminary estimates of the total time in hours required to complete a grader operation is:

$$\text{Total time} = \frac{P \times D}{S \times E}$$

Factors to be considered in the above formula are explained as follows:

The number of passes (P) depends upon the operation.

The distance (D) traveled in each pass is expressed in miles.

Speed (S) is expressed in miles per hour. It is the most difficult factor in the formula to estimate. As work progresses, conditions may require the speed estimates be increased or decreased. The work output is computed for each operation which is performed at a different rate of speed. The sum of the values obtained in each part is the total time required for the operation. Care must be taken to use the correct number of passes for each speed used.

Table 5-2.—Checklist for Grade Efficiency

Leveling	Ditching	Reshaping	Bank sloping	Scarifying	Mixing	Spreading	Snow removal
1. Is blade set at sharp enough angle to get proper slicing action?	1. Is marking cut made approximately 3 to 4 inches deep?	1. Is maintenance performed in least possible number of passes?	1. Is heel of blade at bottom of ditch?	1. Are teeth penetrating too deep so subgrade is torn up and mixed with road surface?	1. Is blade pitched forward to obtain rolling action?	1. Are there any signs that material is not thoroughly mixed?	1. Is grader speed high enough to throw material to one side?
2. Is blade set at proper pitch to get cutting action?	2. Is toe of blade directly behind front wheels?	2. Are shoulders and edges maintained to eliminate standing water?	2. Is blade set to give maximum slicing action?	2. If material is hard and consolidated, are enough teeth removed to give proper penetration?	2. Are graders worked in tandem where possible?	2. Is material being spread to proper thickness?	2. Has preliminary reconnaissance been made to locate any large, heavy objects that may be hidden under snow?
3. Is blade set so windrow falls either inside or outside of rear grader wheels?	3. Is blade set so windrow falls inside of rear wheels?	3. Is material kept on road and not spilled into ditch?	3. Is bank sloping being done in first gear.	3. Is machine traveling as fast as power allows?	3. Is blade taking too much material, preventing free rolling?	3. Are wheels being turned on freshly spread mix, causing a wavy surface?	3. Is care being taken not to damage pavement or portable surface?
	4. Is windrow removed before it reaches underside of grader?	4. Is speed too fast or cut too deep, causing washboarding of surface?	4. Does the rear wheel trail heel of blade?		4. Is speed regulated to give proper mixing action and at the same time to allow full control of grader?		
	5. Is bank slope step-cut?	5. Is speed fast enough to maintain efficient operation?			5. Is blade set to produce a free flow of material?		
	6. Is the heel of the blade lowered to maintain inside slope of ditch?	6. Has operation been planned so flow of traffic is not stopped?					

Mechanical check

1. Are all adjustments to power unit being made?
2. Are edges of blades in good condition?
3. Are proper tire pressures being maintained?

143.114

The grader efficiency (E) factor takes into account the fact that a 60-minute work hour rarely is attained. Efficiency varies, depending upon supervision, operator skill, maintenance requirements, and site conditions. A value of 60 percent is average. It must be verified or adjusted on each job.

An example problem: Five miles of gravel road are to be leveled and reshaped, using a motorized grader with a 12-foot moldboard. Six passes are estimated as required to complete leveling and reshaping. The type of material permits passes 1 and 2 in second gear at 2.8 mph, passes 3 and 4 in third gear at 3.4 mph, and passes 5 and 6 in fourth gear at 5.4 mph. Using an efficiency factor of 60 percent, how long will it take to complete the job?

Substituting in work-output formula:

$$\text{Total time} = \frac{2 \times 5}{2.8 \times 0.6} + \frac{2 \times 5}{3.4 \times 0.6} + \frac{2 \times 5}{5.4 \times 0.6} =$$

$$6.0 + 4.9 + 3.1 = 14 \text{ hours.}$$

ROAD AND RUNWAY COMPACTING OPERATIONS AND DESIGNS

A properly prepared foundation, which includes adequate drainage, both external and internal, and proper compaction during construction, will assure long life of a roadway or runway pavement surface.

The importance of proper compaction of each layer of embankments, subgrades, improved subgrades, and base courses cannot be stressed too strongly. Compaction greatly increases the supporting power of the subgrade. Where the subgrade is not sufficiently compacted during construction, additional consolidation may occur under traffic with resulting settlement and possible failure.

Usually, the EA's within the Battalion will perform compaction tests on the materials to be used in construction to determine the maximum practical density which should be obtained. In compaction testing, the EA's follow test procedures prescribed by the AASHO (American Association of State Highway Officials).

The following criteria for compaction are recommended for construction of cohesive subgrades, cohesionless subgrades, bases, subbases, and improved subgrades.

1. Cohesive Subgrades minimum density should be 95 percent for the top 12 inches and 90 percent minimum for all fill areas below the 12 inches.

2. Cohesionless Subgrades minimum density should be 100 percent for the top 12 inches and minimum 95 percent below this depth for all fill areas.

3. Bases, Subgrades, and Improved Subgrades minimum density should be 100 percent. The compaction load and contact pressure should be as high as the material being compacted will support with displacement. As stronger layers are placed, the load and contact pressure should be increased up to or in excess of the contact pressure expected on the pavement.

Each layer of material should be compacted to specified density. Fill sections generally should be built in layers not exceeding 6 inches after compaction. Heavy pneumatic-tired and vibratory compaction rollers may be satisfactory for lifts up to 12 inches, but these thicker lifts should be used only if tests show that specified density is obtained. In some cases it may be desirable to construct a small test fill to obtain pertinent information on moisture content, thickness of lift, and number of passes with compacting equipment.

In determining the thickness of a lift, it should be noted that the effectiveness of a compactive effort on a lift decreases with depth. Hence, each lift will usually be more compacted at the top than at the bottom, and the less thorough the compaction, the greater will be the difference. This depth effect is reduced by vibration in materials responding to it (dry or saturated cohesionless materials). Kneading action also is an aid, especially in material whose resistance to compaction is derived from both cohesion or viscosity and granular interference.

The same considerations apply in lesser degree to asphaltic lifts because they usually are thinner.

The compaction criteria for subgrades apply for cut sections also. At least 12 inches of soil should be removed, adjusted to proper moisture content, replaced in thin layers and recompacted to produce the specified density. This arrangement also tends to produce uniformity in the subgrade, thus avoiding differential settlement. In any case, the required densities must be obtained if the pavement is to provide proper service.

Although compaction increases the stability of most soils, some soils decrease in stability when scarified, worked and rolled. There are also some soils that shrink excessively when allowed to absorb moisture. When these conditions are encountered, special treatment is required, and the EA's should be consulted. Soils in which these conditions occur are: clays which lose strength when remolded, silts that become "quick" when remolded, and soils with expansive characteristics.

If it is difficult to obtain compaction in a given material, it may be necessary to reduce the thickness of the layer.

Higher contact pressures improve compaction, particularly with granular materials. However, pressures should not be so high as to shear the soil. With pneumatic-tired rollers, contact pressures can be increased more and with greater ease by increasing the tire pressure than by adding weight.

Vibrating rollers are particularly good for consolidating granular materials.

Tamping or sheepsfoot rollers are extensively used and are effective with a wide variety of soils. However, they should not be used with non-plastic granular materials because of a displacement in these soils. Considerable compactive effect is obtained from construction equipment transporting the fill material. To insure uniform compaction, construction equipment should distribute its travel as uniformly over the fill area as possible. In addition, heavy loaded earth movers usually will locate an unstable foundation; if they develop, these areas should be removed and reconstructed.

Proof rolling often is done on road and runways during construction to increase the density of the soil and locate soft and unstable areas.

Proper moisture content is necessary for compacting the soil to the prescribed density. The percent of moisture at which the maximum density can be obtained at a compactive effort is called the "optimum moisture content," and it varies with different types of soils. Water should be added if too dry; water should be removed by aeration if too wet. Manipulation by the use of motorized graders, towed harrows, or rotary tiller mixers is a common method of aeration.

If there is an interruption of the compaction operation, windrowing the material will lessen the loss of moisture or will help shed water in case of rain.

The moisture content of material from a borrow pit can be increased before it is brought on the site by adding moisture at the source. Moisture control usually is better if a mixing plant is used.

Table 5-3 (foldout at the end of this chapter) gives the engineering characteristics pertinent to roads and airfields of soil groups of the Unified Soil Classification System. You may not be familiar with the abbreviation CBR, which appears in the heading of column 15 of this table. In that case, let us explain that CBR, as used in table 5-3, stands for California Bearing Ratio, which is a test to measure relative bearing capacity of soils and base material.

The design of a road or runway pavement structure must start with an analysis and classification of the existing subgrade or soil foundation. The properties that affect the performance of the soil, such as grain sizes, moisture content, and bearing capacity, must be determined.

Soils ordinarily must be protected from overstress by covering them with a subbase course, a base course, and a wearing course. Weak (low-bearing capacity) soils often are covered to depths of several feet, and some very weak soils must be removed altogether or consolidated by means of vertical drains before the overlaying courses are placed.

The granular aggregates placed over the subgrade soils are known as base and subbase aggregates. The base aggregates, used in the top layers immediately under the pavement, are carefully prepared and are of high quality. Their performance properties are improved by treating them with asphalt. The subbase aggregates may be of lower quality, since they are deeper in the pavement structure where stresses from wheel loads are smaller. These base and subbase aggregates serve to spread the loads over the soil subgrades.

The subgrade is the uppermost soil material placed in embankments or unmoved material from cuts in the normal grading of the roadbed. It is the foundation for the asphalt pavement structure.

Soil for construction purposes may be defined as a natural aggregate of mineral particles which can be separated by gentle agitation, and which may or may not contain organic matter. Since it encompasses a very wide variety of materials, soil must be classified by type according to the properties which may affect its performance in the subgrade. These soil classifications are discussed in the chapter entitled "Principles of Earthwork" in *Equipment Operator 3 & 2,* NAVEDTRA 10640-H.

SOIL-CEMENT STABILIZATION AND APPLICATION

Through the years, many efforts were made to combine soil and cement to produce a satisfactory low-first-cost paving material. The idea dates back to 1917, when various state highway agencies in the United States experimented with adding cement to subgrade soils to increase stability. In 1933 and 1934, the South Carolina State Highway Department succeeded in building short sections of soil-cement highway. The results were promising enough to stimulate research in the use of soil-cement mixtures. Today, you can find soil-cement mixtures being used not only in the construction of roads but in the construction of airfields, parking areas, drainage ditches, canal linings, sidewalks, helipads, and more.

TYPES OF SOIL-CEMENT

Soil-cement is a simple, intimate mixture of pulverized soil and measured amounts of portland cement and water, compacted to high density. As the cement hydrates, the mixture becomes a hard durable paving material. There are three general types of soil and cement mixtures:

1. Compacted soil-cement
2. Cement-modified soil
3. Plastic soil-cement

Compacted soil-cement contains sufficient cement to harden the soil and enough moisture both for adequate compaction and for the hydration of the cement. For purposes of this training manual, all mixtures of soil and cement are classified as soil-cement or cement-modified soil without regard to the type or source of soil or aggregate.

Cement-modified soil is an unhardened or semihardened mixture of soil and cement. When relatively small quantities of portland cement and moisture are added to granular soil or silt-clay soil, the chemical and physical properties of that soil are changed. Cement reduces the soil's plasticity and its water-holding capacity and increases its bearing value. The degree of improvement depends upon the quantity of the cement used and the type of soil. In cement-modified soil, only enough cement is used to change the physical properties of the soil to the desired degree—less cement is used than is required to produce a hard soil-cement. Cement-modified soils may be used for base courses, subbases, treated subgrades, highway fills, and as trench back-fill material.

Plastic soil-cement is also a hardened mixture of soil and cement that contains, at the time of placing, sufficient water to produce a consistency similar to that of plastering mortar. By comparison, compacted soil-cement is placed with only sufficient moisture to permit adequate compaction and cement hydration. Plastic soil-cement is used to pave steep, irregualr or confined areas such as highway ditch linings and other erosion-control structures, where it is difficult if not impossible to use roadbuilding equipment.

MATERIALS FOR SOIL-CEMENT

Only three basic materials are needed in soil-cement: soil, portland cement, and water. Low-first-cost is achieved mainly by using cheap local materials. The soil, which makes up the bulk of soil-cement, is either in place or obtained nearby, and the water is usually hauled only short distances.

The word "soil," as used in soil-cement, means almost any combination of gravel, sand, silt, and clay, and includes such materials as cinder, caliche, shale, laterite, and many waste materials.

The materials usually found in old gravel or stone roadways and runways make excellent soil-cement. These materials generally are friable (easily crumbled), mix easily, and require only a minimum amount of cement. Frequently, an old bituminous surface can be salvaged or can be pulverized and mixed with the old base-course material for processing with cement.

If an old bituminous surface is practically "dead"–that is, has lost most of its flexibility–it may be satisfactory for inclusion in the soil-cement mixture. If, on the other hand, the surface is "alive" and the bituminous material retains most of its original viscosity, it should not be incorporated in the mixture, but should be removed. It may be considered worthwhile to reclaim and replace it on the soil-cement with the addition of new materials as needed.

The quantities of portland cement and water to be added and the density to which the mixture must be compacted are determined by tests. The water serves two purposes: it helps to obtain maximum compaction (density) by lubricating the soil grains, and it is necessary for cement hydration, which hardens and binds the soil into a solid mass. Soil-cement properly built contains enough water for both purposes.

The cement should be any type of portland cement that complies with the requirements of the latest AASHO, ASTM (American Society for Testing Materials), or federal specifications. Normal and air-entraining portland cements are most commonly used.

The water used in soil-cement should be relatively clean and free from harmful amounts of alkalies, acid, or organic matter. Any fresh water is satisfactory. Sometimes, seawater has been used satisfactorily when fresh water was unobtainable.

Practically all soils and soil combinations can be hardened with portland cement. They do not need to be well graded "aggregates" since stability is attained primarily through the hydration of cement and not by cohesion and internal friction of the materials. The general suitability of soils for soil-cement can be judged before they are tested, on the basis of their gradation and their position in the soil profile. On the basis of gradation, soils for soil-cement construction can be divided into three broad groups:

1. Sandy and gravelly soils with about 10 to 35 percent silt and clay combined have the most favorable characteristics and generally require the least amount of cement for adequate hardening. Glacial and water-deposited sands and gravels, crusher-run limestone, caliche, laterite, limerock, and almost all granular materials work well, if they contain 55 percent or more material passing the No. 4 sieve. Exceptionally well graded materials may contain up to 65 percent gravel retained on the No. 4 sieve and have sufficient fine material for adequate binding. These soils are readily pulverized, easily mixed, and can be used under a wide range of weather conditions.

2. Sandy soils deficient in fines, such as some beach sands, glacial, and windblown sands, make good soil-cement though the amount of cement needed for adequate hardening usually is slightly greater than with the soil in Group 1. Because of poor gradation and absence of fines in these sands, construction equipment may have difficulty in obtaining traction. Traction can be vastly improved by keeping the sand wet and by using track-type equipment. These soils are likely to be "tender" and to require care during final packing and finishing so that a smooth, dense surface may be obtained.

3. Silty and clayey soils make satisfactory soil-cement but those containing high clay contents are harder to pulverize. Generally, the more clayey the soil, the higher the cement content required to harden it adequately. Construction with these soils is more dependent on weather conditions. If the soil can be pulverized, it is not too heavy-textured for use in soil-cement.

SOIL-CEMENT TESTS

The Battalion Engineering Aids conduct laboratory tests to determine the three fundamental control factors for soil-cement, which are:

1. Proper cement content
2. Proper moisture content
3. Proper density

An adequate cement content is the first requisite for quality soil-cement. Well in advance of construction, the soils on the project should be identified, the limits of each soil defined, and a representative sample of each soil type forwarded to the materials testing laboratory to determine the quantity of cement required to harden it. A soil survey of the construction area should be made.

A soil survey includes the examination of soils on a project, a description of these soils, and a location of the limits of extent of the various soils. Experience and a good working knowledge of soils are valuable aids to EA's making complete soil surveys.

Proper soil surveying, identification, and sampling are important. For instance, if one soil type were sampled and tested while actual construction involved a different soil, the tests would be worthless and, in fact, detrimental since they would mislead your operators.

Soil samples are usually taken from a graded roadway by digging a trench from the centerline to the edge of the proposed roadway or pavement and to the depth of processing. Soil samples for proposed roadways or runways not yet graded are taken from the various soil layers of each soil type from the "dressed-down" face of exposed cuts, or from the surface with an earth auger. Samples should be taken so that only one soil type is represented by each sample. Similarly, it is not good practice for the EA's to take a composite sample from various locations. Data obtained from a composite sample do not apply to soil in any single location and may be misleading to you and the operators. There are exceptions: for instance, in sampling pit material that is to be loaded during construction by a shovel operating over the vertical face of the pit, the sample is taken from bottom to top of the vertical face after the overburden has been removed. On small projects, it is not uncommon to sample only the poorest soil on the job. The cement content for this sample is used throughout the job. The EA's must be sure that complete identification is supplied to you with each sample they have taken.

For information only, an outline is given here of the tests the EA's will normally run on soil samples submitted for soil-cement construction. The objective of these tests is to determine the minimum cement content required to harden each soil adequately. The following tests are usually run:

Soil identification tests

Grain size
Liquid limit
Plastic limit

Soil-cement tests

Moisture-density relations
Wetting and drying test
Freezing and thawing test

Unconfined compressive-strength tests are also made.

The moisture-density test establishes the optimum moisture and maximum density at which test specimens should be molded. It also provides approximate values for use in construction. Wet-dry and freeze-thaw test specimens containing various amounts of cement are molded at optimum moisture and maximum density and tested after 7 days' hydration to determine the lowest cement content that will harden the soil adequately.

INSPECTION AND FIELD CONTROL

The purpose of inspection and field control is to assure that the results set out in plans and specifications are obtained. As mentioned before, there are three major control factors in soil-cement construction. They are:

1. Adequate cement content
2. Proper moisture content
3. Proper compaction

A thorough mix of pulverized soil, cement, and water must also be obtained. To assist in attaining these objectives, the following list of check items is given:

1. Inspection of the grade and correction of all soft subgrade areas.
2. Proper identification of the soils so that the correct percentage of cement may be added to each soil.
3. Adequate pulverization.
4. Calculation of cement spread.
5. Proper amount of cement spread.
6. Incorporation of the correct amount of moisture.
7. Uniformity of mix; depth and width of treatment.
8. Degree of compaction–density.
9. Proper finishing.
10. Adequate curing.

Proper inspection is primarily good judgment based on experience and the requirements of the plans and specifications. Many of the items are automatically controlled as the operator learns the proper construction procedures.

Before construction starts, the area to be paved should be graded and shaped as required to construct the base course to the lines, grades, thickness, and typical cross section that are shown on the plans.

During grading, all debris should be removed and all soft subgrade areas corrected. The latter is important since adequate compaction cannot be obtained in the base course if the subgrade does not support the compacting and finishing equipment. Most soft areas can be easily detected by observing the stability as the grader shapes the area prior to soil-cementing.

The success of soil-cement depends mainly on mixing the correct amount of cement with the soil. The soil survey report, laboratory test reports, plans, specifications, and the EA's knowledge of the soils on the job can supply you with the information needed. On most jobs, this is a simple step since only one or possibly two cement contents are needed. Usually cement requirements and soil types have been established long before construction starts, but they should be checked.

Most soils used in soil-cement construction need little or no preliminary pulverization. Specifications generally require that at time of compaction 80 percent of the soil-cement mixture pass the No. 4 sieve and 100 percent pass the 1-inch sieve, exclusive of any gravel or stones retained on these sieves. If a clayey soil is being used, the degree of pulverization needs to be checked. The degree of pulverization required before cement is added depends on the soil and the mixing equipment.

HANDLING CEMENT

As a supervisor, you will be responsible for directing the handling of cement in soil-cement construction operations. You will want to insure that your operators are familiar with the equipment they use and know how to use the equipment efficiently in operations involving the handling or spreading of cement.

Various types of equipment are used in handling cement. Some of the most commonly used types are illustrated in figures 5-1 through 5-9.

On mixed-in-place construction, bulk cement is spread on the area to be processed in required amounts by mechanical bulk cement spreaders. Bag cement is sometimes used on small jobs.

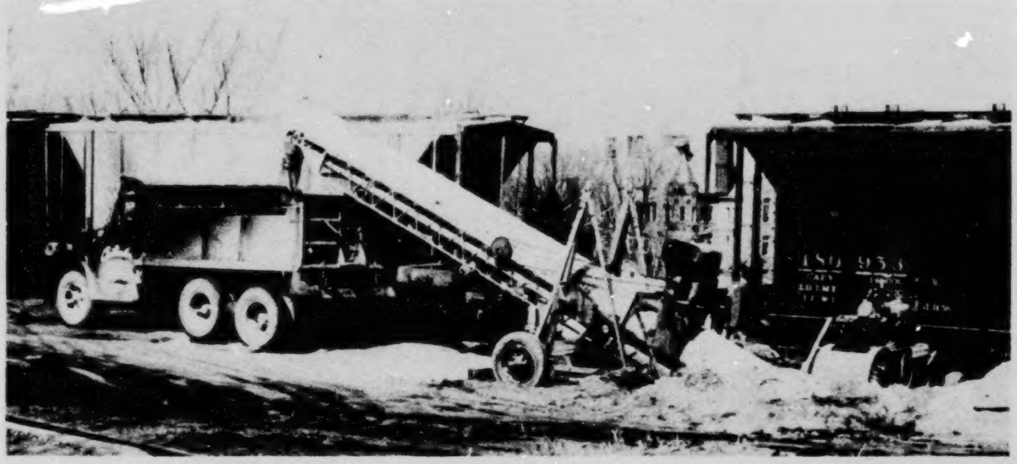

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Figure 5-1.—Belt conveyor unloading bulk portland cement from a hopper-bottom railroad car.

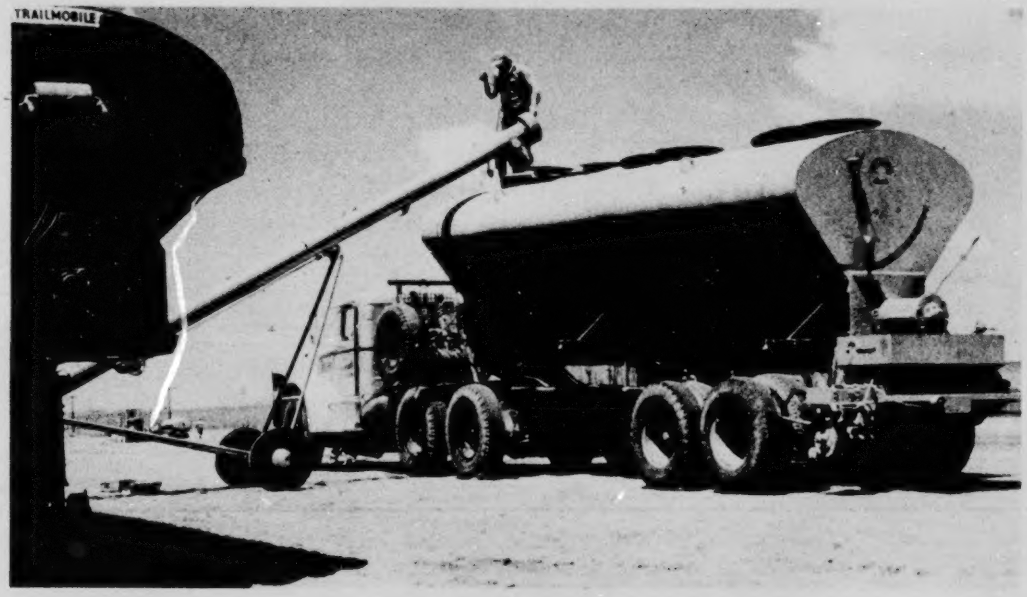

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Figure 5-2.—Screw conveyor unloading bulk portland cement from a transport truck.

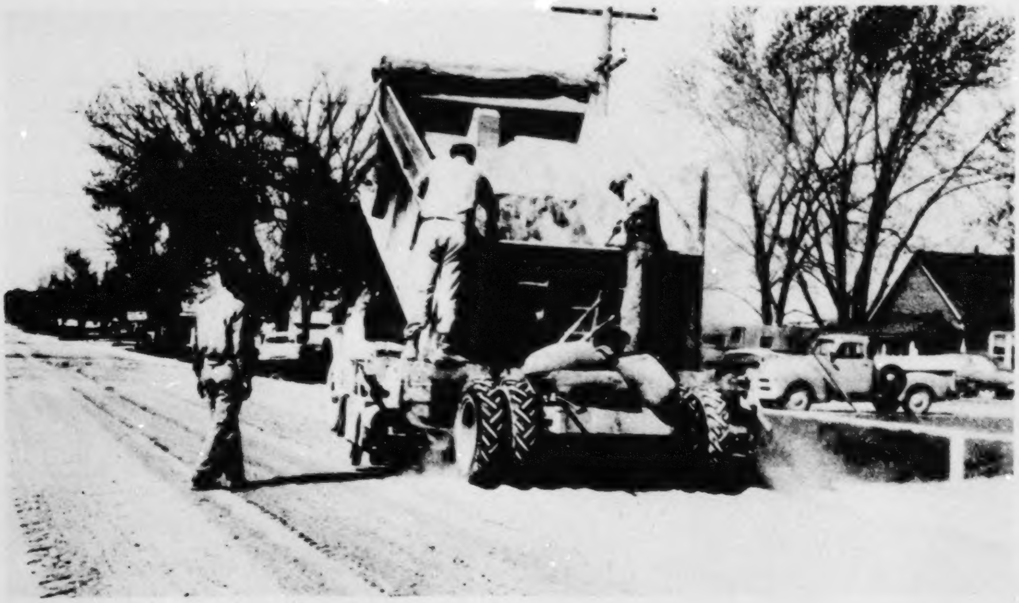

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Figure 5-3.—Mechanical cement spreader attached to dump truck.

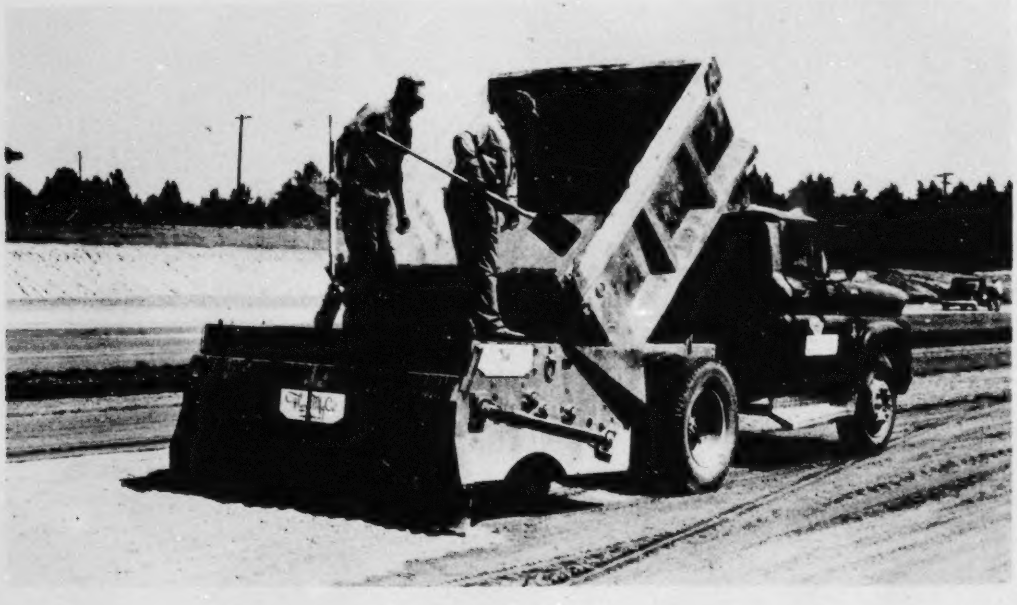

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Figure 5-4.—Loading mechanical cement spreader.

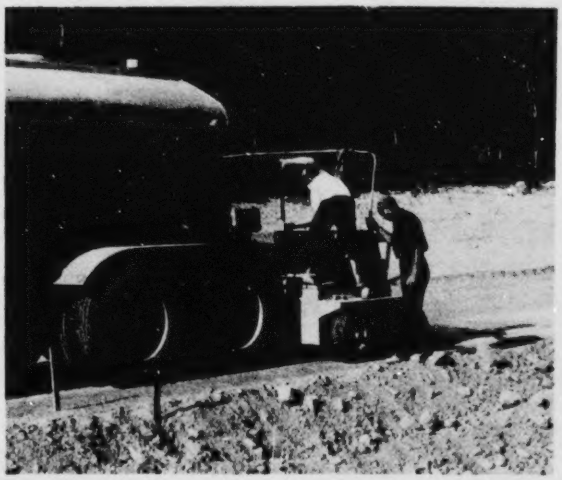

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Figure 5-5.—Mechanical cement spreader attached to a transport truck.

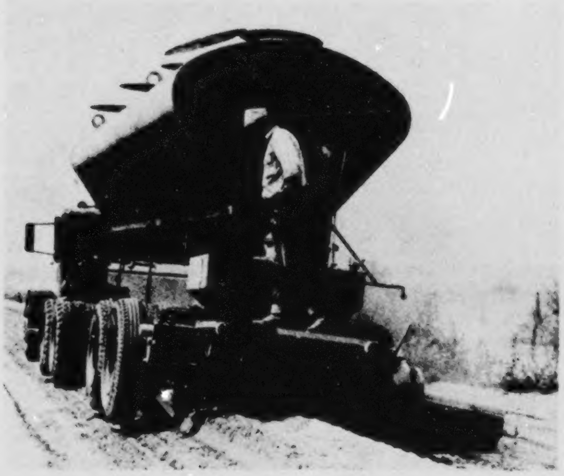

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Figure 5-7.—Windrow-type mechanical spreader.

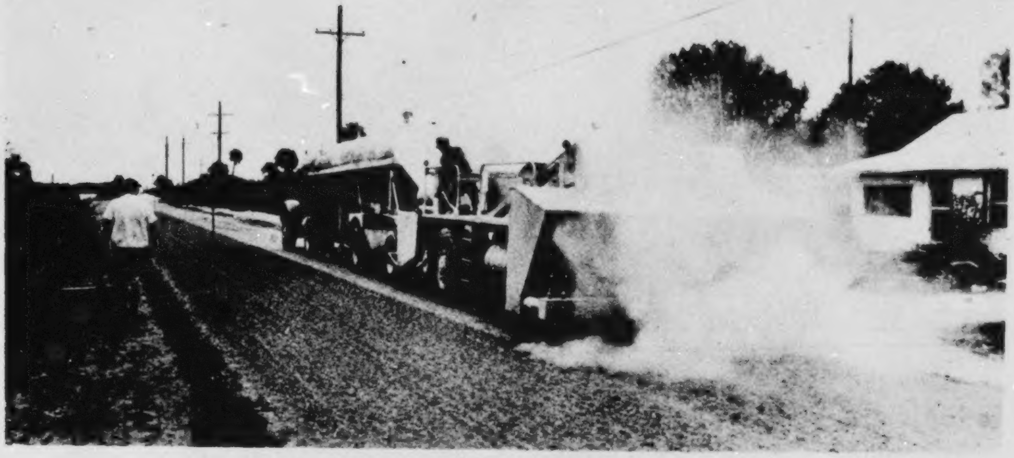

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Figure 5-6.—Self-propelled mechanical cement spreader.

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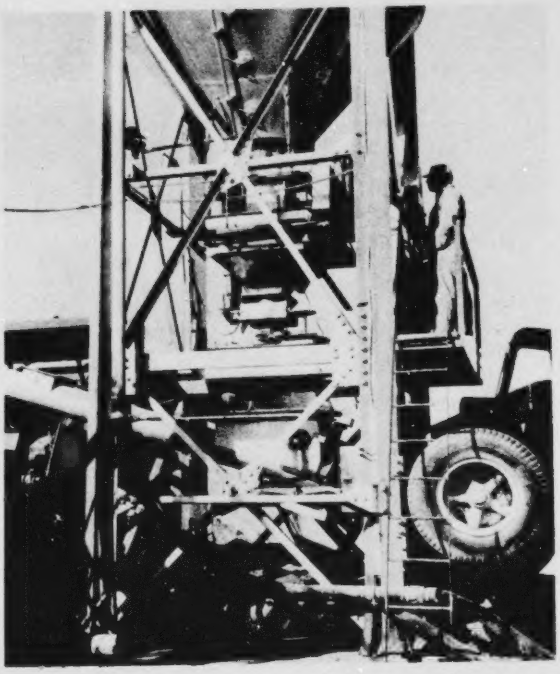

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Figure 5-8.—Cement fed to pugmill by a screw auger feeder.

Cement spreaders for mixed-in-place construction are of two general types: those that spread cement over the soil in a blanket and those that are designed to deposit cement on a windrow of soil. Cement meters on central mixing plants are of three types: the belt with strike-off, screw, or vane type.

The mixing of soil, cement, and water is accomplished by any of several types of equipment. Whatever type of mixing equipment is used, the general principles and objectives are the same. Some of those types of mixing equipment used are illustrated in figures 5-10 through 5-18.

ROAD CONSTRUCTION

Soil-cement road construction involves two steps–preparation and processing. Regardless of the equipment and methods used, it is essential to have an adequately compacted, thorough mixture of pulverized soil and the proper amounts of cement and moisture.

Before construction starts, the crown and grade of the roadway should be checked and any fine grading should be completed. Since there is little displacement of soil during processing, the

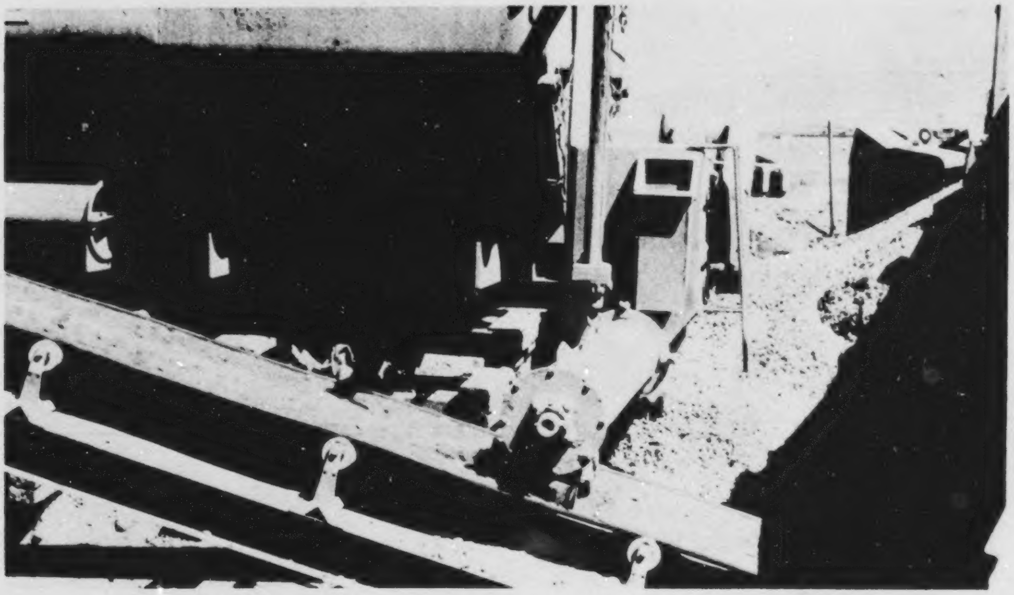

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Figure 5-9.—Metered cement carried to screw feeder by means of a continuous belt.

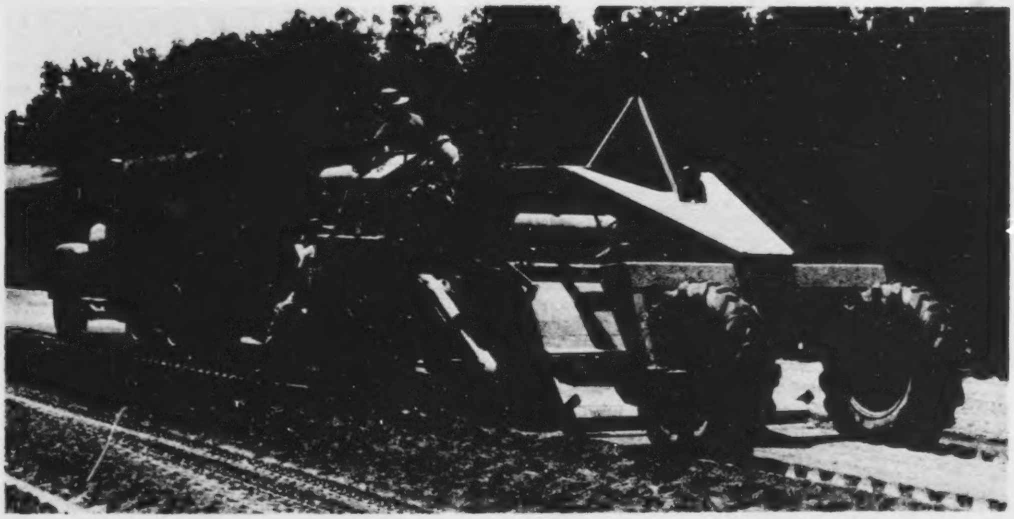

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Figure 5-10.—Self-propelled, single-shaft mixer processing soil-cement in place.

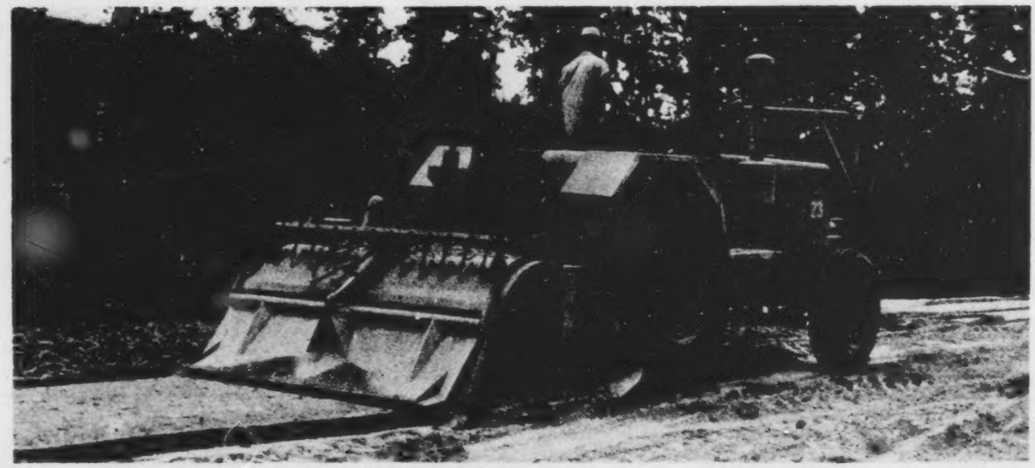

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Figure 5-11.—Laying a single-pass with a self-propelled, single-shaft mixer.

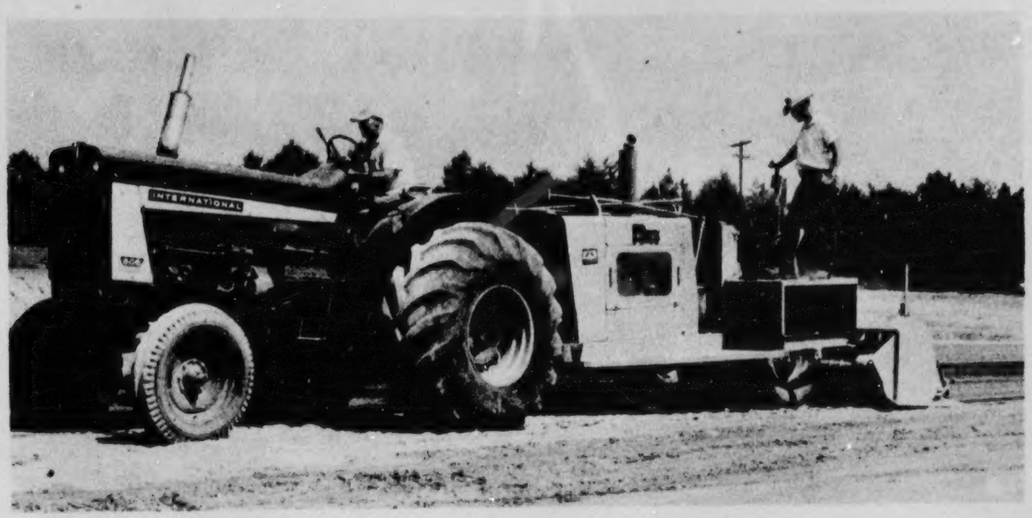

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Figure 5-12.—Pull-type single-shaft mixer.

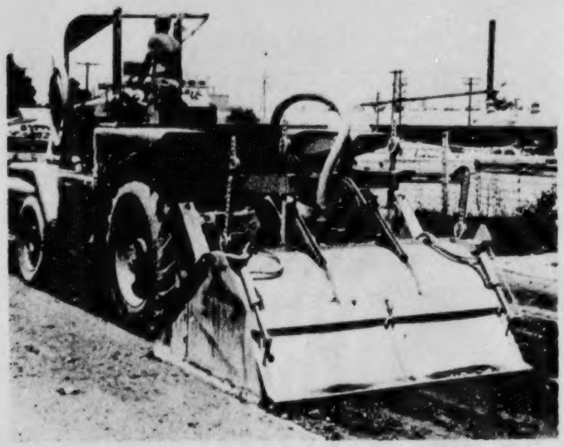

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Figure 5-13.—Pulverizing with self-propelled, single-shaft mixer.

grade at the start of construction will determine the final grade to a major extent. If borrow soil is to be used, the subgrade should be compacted and shaped to proper crown and grade before the borrow is placed. Any soft subgrade areas should be corrected.

To avoid later costly delays, all equipment should be carefully checked to insure that it is in good operating condition and meets the construction requirements of the job.

Guide stakes should be set to control the width of treatment and to guide your operators during construction.

Arrangements should be made to receive, handle, and spread cement and water efficiently. The number of cement and water trucks required depends on the length of haul, condition of haul roads, and anticipated rate of production. For maximum production, an adequate cement and water supply is essential.

The limits of the different soil types and their corresponding cement requirements should be established by the Engineering Aids.

Depending upon the type of soil and mixing equipment, the soil may need to be scarified, pulverized, and prewet. Friable soils, which are most commonly used, require little or no scarification or pulverization. Silty and clayey soils may require extra effort to pulverize them, particularly if they are too dry or too wet. There are two keys to easier pulverization:

1. Proper moisture control
2. Proper pulverization equipment

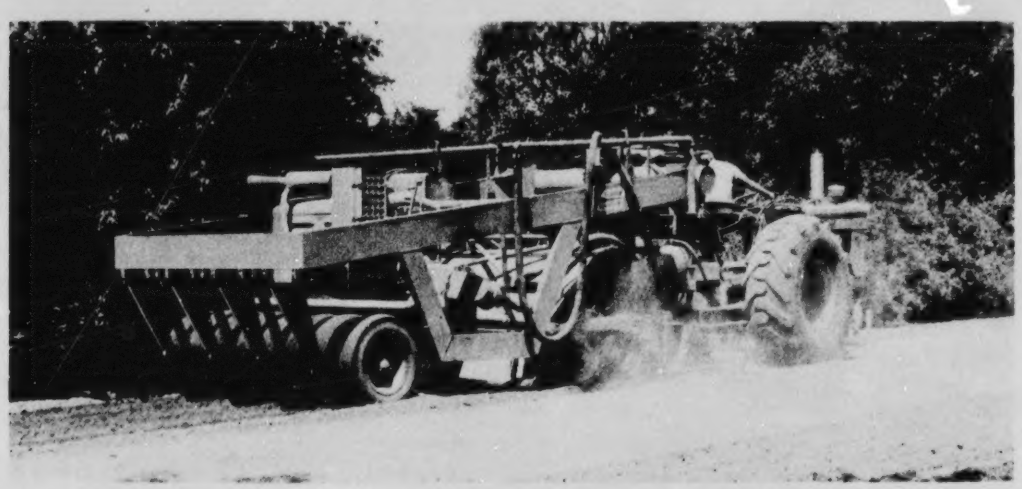

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Figure 5-14.—Self-propelled, single shaft mixer with compactor unit at the rear.

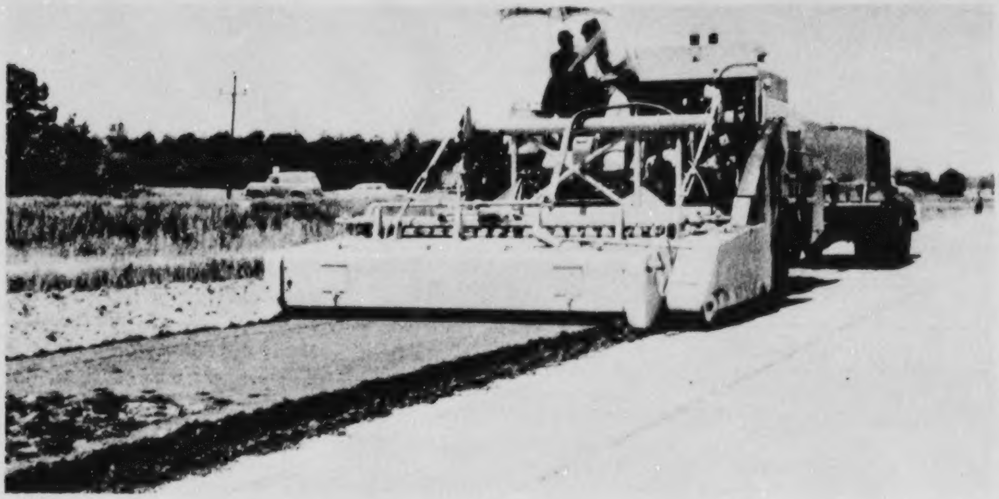

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Figure 5-15.—Multiple-shaft mixer mixing soil, cement, and water in one pass.

Soils that are difficult to pulverize when dry and brittle can be broken down readily if water is added and allowed to soak in, whereas sticky soils can be pulverized more easily when they are dried out a little. Proper pulverization equipment will help reduce pulverization work to a minimum.

Most specifications require that the soil be pulverized sufficiently and that, at the time of compaction, 100 percent of the soil-cement

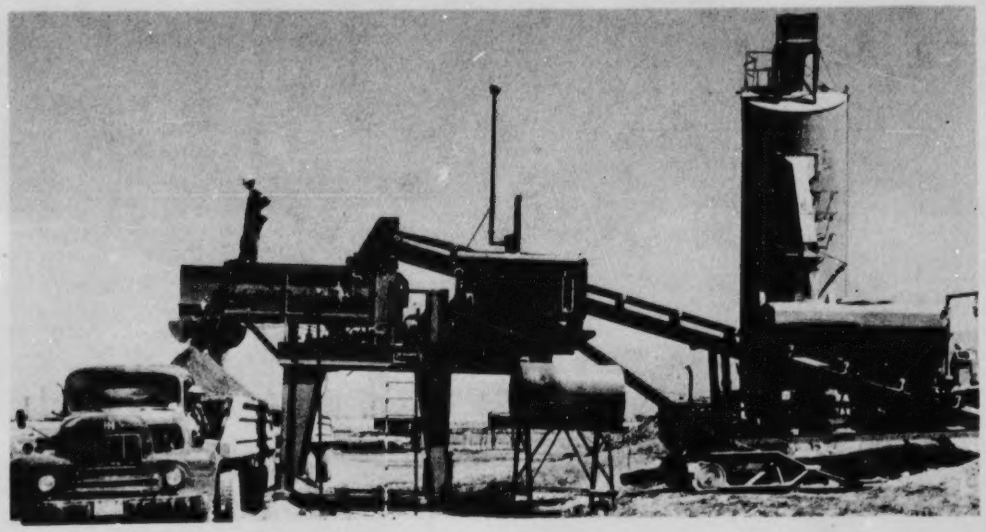

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Figure 5-16.–Twin-shaft, continuous-flow stationary plant mixing soil, cement, and water.

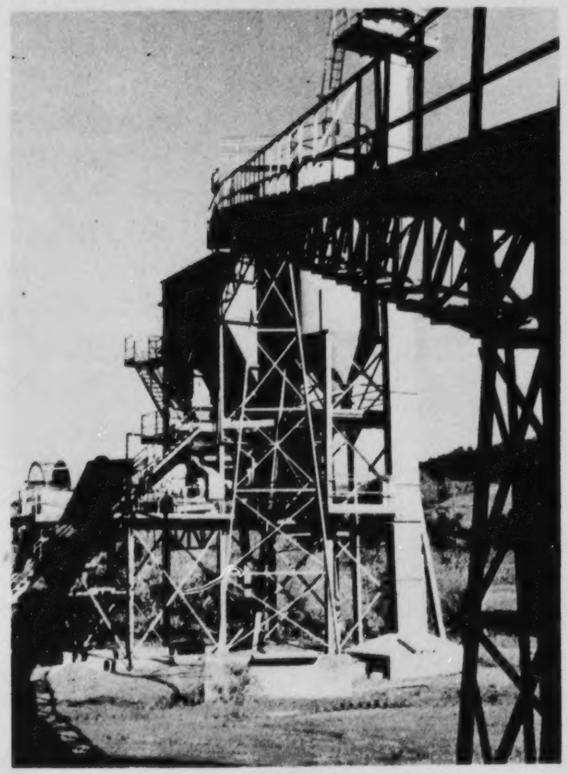

Figure 5-17.–Batch-type plant used for central mixing of soil-cement. 143.154X

mixture will pass a 1-inch sieve and a minimum of 80 percent will pass a No. 4 sieve, exclusive of any gravel or stone. Gravel or stone should be of 2-inch maximum size. The final pulverization test is made at the conclusion of mixing operations.

Prewetting by adding moisture before cement is applied often helps in scarifying and pulverizing the soil and often saves time during actual processing operations.

When borrow soil is specified, it should be distributed on an accurately graded, well-compacted roadway in an even layer or in a uniform windrow, depending upon the type of mixing equipment to be used. It may be placed by weight or by volume as required by specifications.

For maximum efficiency and to meet specification time limits, the day's work should be broken down into several sections rather than building one or two long sections. This procedure will result in maximum daily production and will prevent a long stretch of road from being "rained out" in case of a sudden, severe rainstorm.

Bulk cement is trucked to the jobsite in bulk transport trucks or shipped to the nearest

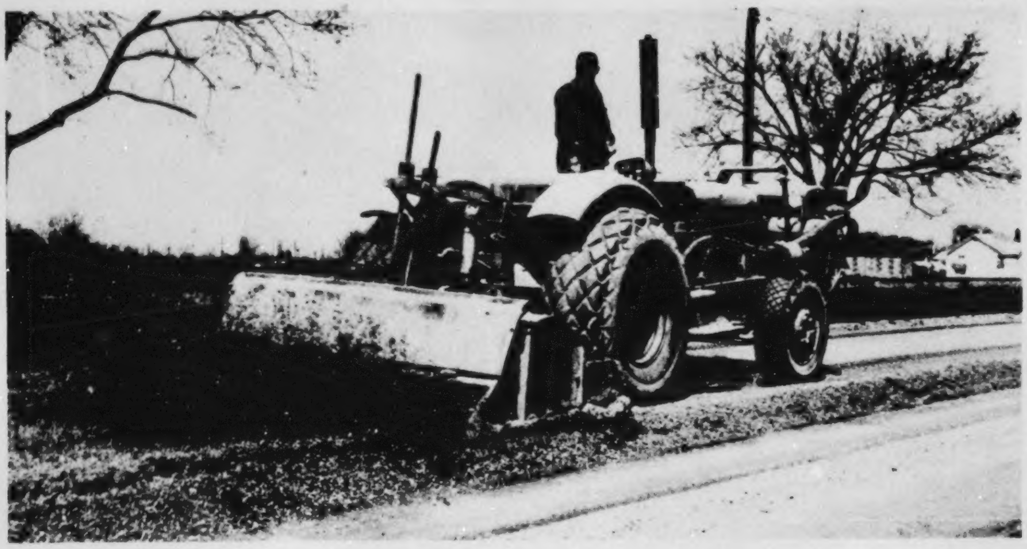

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Figure 5-18.—Single-shaft traveling mixer aerating wet soil.

railroad siding in enclosed hopper-bottom cars. Poles, compressed air, or vibrators are used to loosen the cement in the hopper-bottom cars during unloading. The cement is then transferred to the job in cement trucks, which are enclosed or fitted with canvas covers. Either a screw or belt conveyor is used for the transfer (figs. 5-1 and 5-2). Truckloads of cement are weighed on portable platform scales.

Soils that contain excessive amounts of moisture will not mix readily with cement. Sandy soils can be mixed with a moisture content at optimum or slightly above, while clayey soils should have a moisture content below optimum when cement is spread. Cement should not be applied in puddles of water. If the soil is excessively wet it should be aerated and dried before cement is applied.

When a mechanical cement spreader is being used, the spreader may be attached to a dump truck. With this setup, the truck moves forward and cement flows through the spreader, which regulates the quantity of cement spread on the prepared soil. To obtain a uniform cement spread, the spreader should be operated at a constant, slow speed and with a constant level of cement in the hopper. A true line at the roadway edge should be maintained by using a string line.

The mechanical cement spreader must have adequate traction to produce a uniform cement spread. When operating in loose sands or gravel, where traction may be a problem, slippage of the wheels can be overcome by the use of chains or cleats on the spreader wheels, or by other modifications to the spreader.

At times, a self-powered mechanical spreader (fig. 5-6) is linked to a cement transport truck. With this setup, the spreader pushes the truck forward and cement is dispensed from a large-capacity rear hopper through dispensing screws.

Pipe cement spreaders attached to cement transport trucks have also been used in some areas with variable results.

The amount of cement required is specified as percent by volume of the compacted mixture, or percent by weight of the oven-dry soil. Figure 5-19 can be used to convert from one to the other if the maximum dry density of the

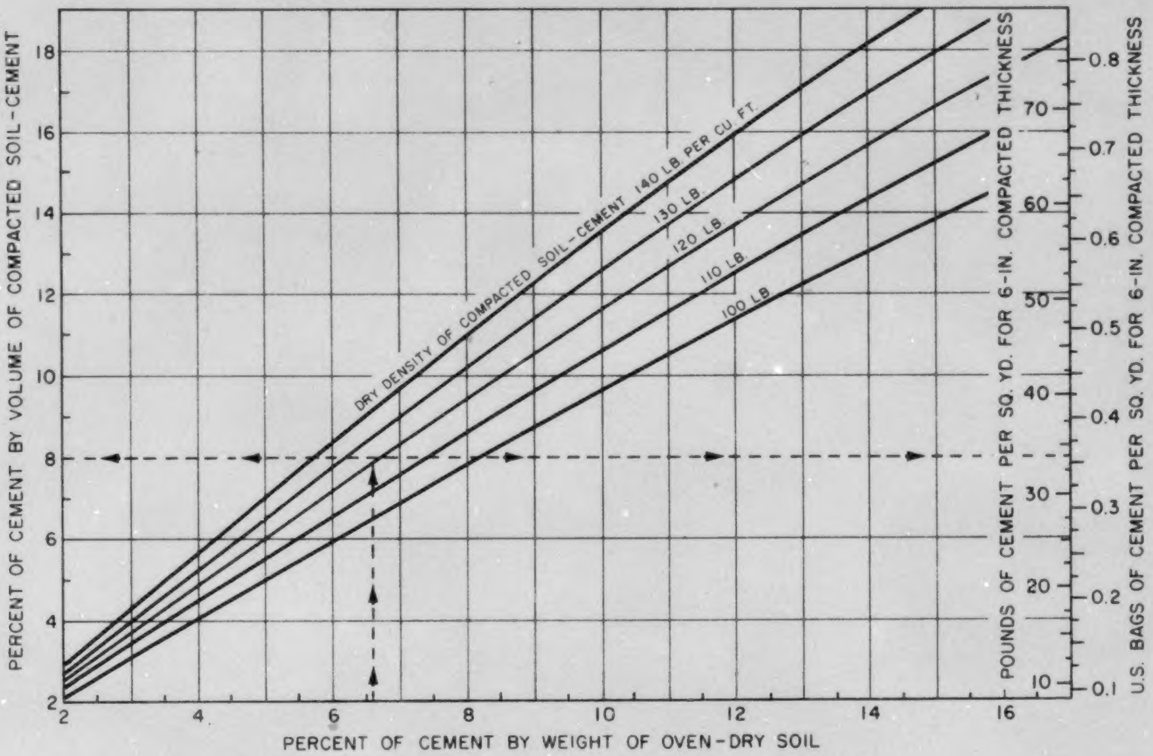

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Figure 5-19.—Cement factor conversion chart.

compacted soil-cement is known. One bag of cement weighs 94 pounds and its volume is considered to be 1 cu ft.

Figures 5-20 and 5-21 and table 5-4 can be used to determine quantities of cement per square yard or per linear foot of roadway.

An example of the determination of the linear distance a truckload of cement should travel to spread the required amount of cement is given below:

Given:

Required cement content, by volume	8 percent
Depth of compacted soil-cement	6 in
Width of spread	8 ft
Weight of truckload of cement	7,520 lb

Procedure: Enter Figure 5-20 on the left edge at 8 percent cement and proceed horizontally to the 6-in. depth line; proceed vertically upward to intersection with line representing 8-ft. width of spread; then proceed horizontally to the right edge and read the pounds of cement per linear foot require: 30.0 lb

Answer: The required distance of travel for the 7,520-lb truckload to obtain the specified cement spread equals the total weight of cement on the truck divided by the pounds per linear foot required:

$$\frac{7,520}{30.0} = 250.7 \text{ ft}$$

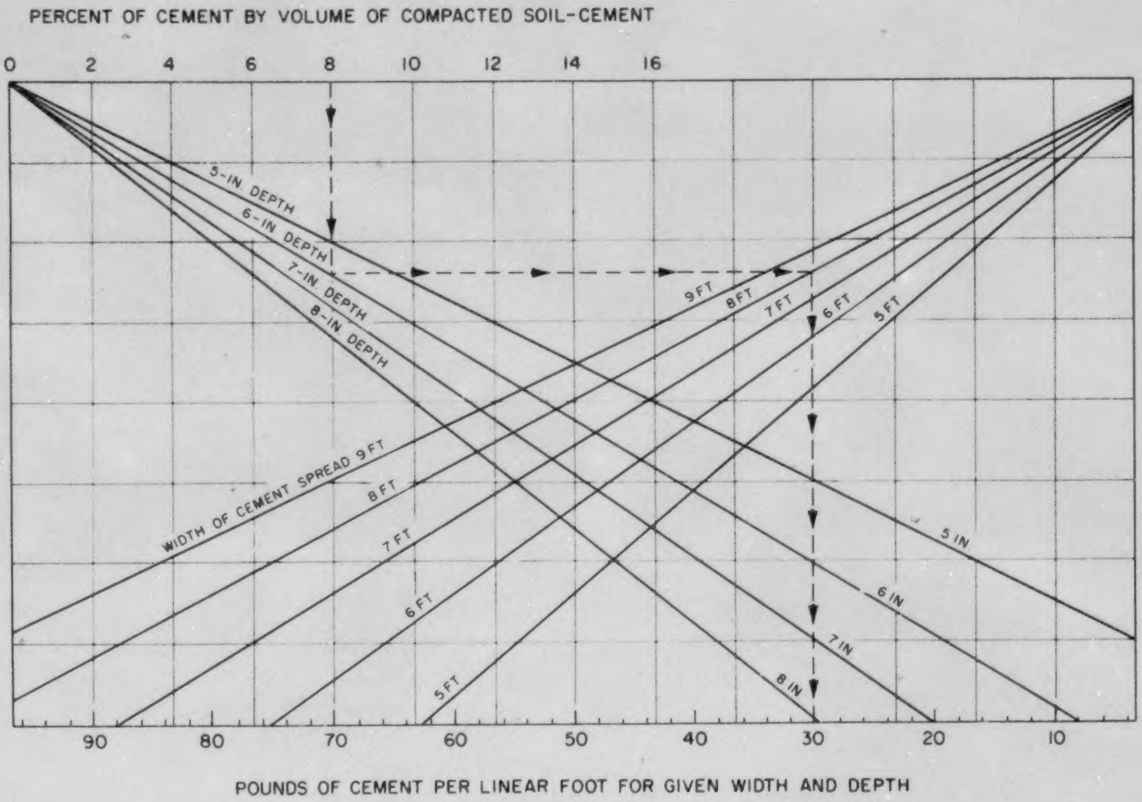

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Figure 5-20.—Pounds of cement required per linear foot for various widths and depths for specified cement contents by volume.

If bag cement is being used, some simple but exact method for properly spotting the bags is necessary. Bags can be spotted by flags or markers fastened to chains at proper intervals to mark transverse and longitudinal rows. The bags should be spaced at approximately equal transverse and longitudinal intervals sufficient to insure that the proper percentage of cement will be added (fig. 5-22). When the bags are opened, cement is dumped so that it forms fairly uniform transverse windrows across the area being processed. A drag then makes at least two round trips over the area to spread the cement uniformly. A spike-tooth harrow, nail drag, or length of chain-link fencing can be used for spreading the cement evenly (fig. 5-23).

When a continuous-flow central mixing plant is being used, the cement is usually metered onto the soil aggregate and the two materials carried to the pugmill mixer on the main feeder belt (fig. 5-16). The change of loss of cement due to wind can be minimized by the use of a small plow attachment which forms a furrow for the cement in the soil aggregate. After the cement is added, a second plow attachment a little farther up on the main feeder belt closes the furrow and covers the cement. The use of a cover on the main feeder belt will also minimize cement loss due to wind.

The three types of cement meters—belt, screw, or vane—can be used to proportion the cement on a volumetric basis. Each requires the use of a 5- to 8-bbl-capacity surge tank or hopper between the cement silo and the cement feeder. This tank maintains a constant head of

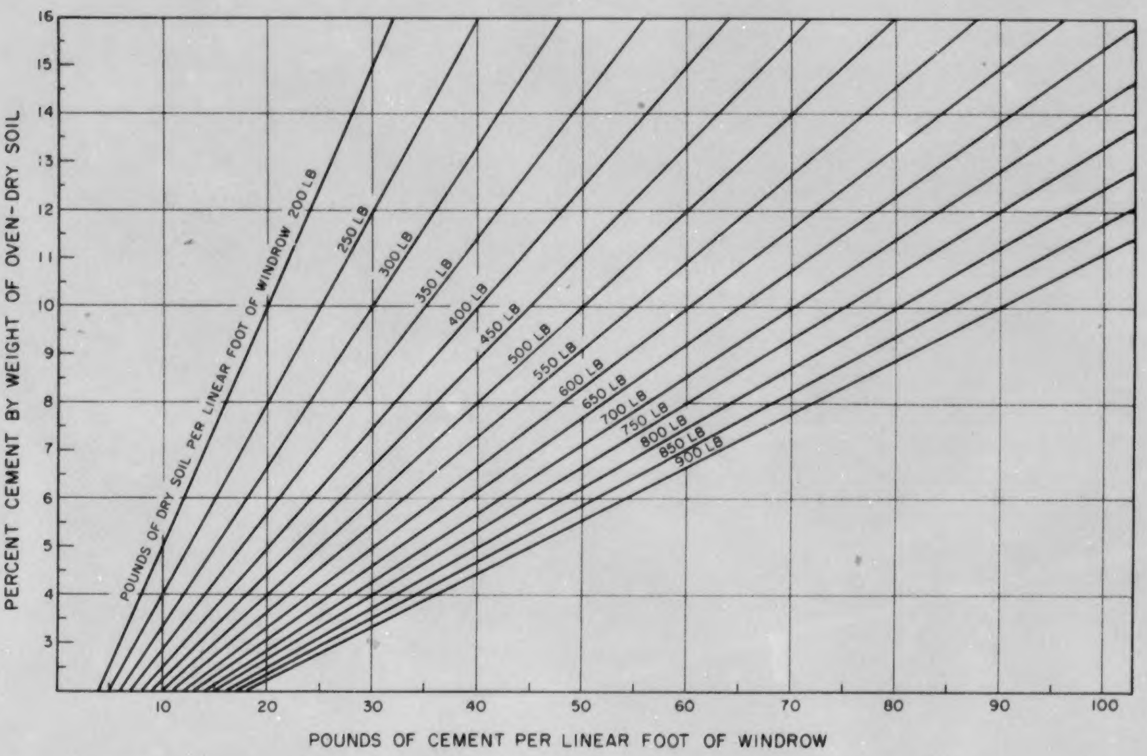

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Figure 5-21.–Pounds of cement required per linear foot of windrow for specified cement contents by weight.

Table 5-4.–Cement Spread Requirements, Pounds Per Square Yard

Percent cement by volume	Compacted depth, inches			
	5	6	7	8
4	14.1	16.92	19.74	22.56
5	17.625	21.15	24.675	28.2
6	21.15	25.38	29.61	33.84
7	24.675	29.61	34.545	39.48
8	28.2	33.84	39.48	45.12
9	31.725	38.07	44.415	50.76
10	35.25	42.3	49.35	56.4
11	38.775	46.53	54.285	62.04
12	42.3	50.76	59.22	67.68
13	45.825	54.99	64.155	73.32
14	49.35	59.22	69.09	78.96
15	52.875	63.45	74.025	84.6
16	56.4	67.68	78.96	90.24

143.197X

cement for the feeder, thus providing a more uniform cement discharge. Compressed air, 2 to 4 psi pressure, should be used to prevent arching of cement in the silo and surge tank. A positive system should be included to stop the plant automatically if the cement flow suddenly stops.

The correct proportion of cement and soil aggregate entering the mixing chamber must be determined by calibrating the plant. One method of doing this is first to run the soil material through the plant for a given period of time and collect it in a truck. This can be done for periods such as 1, 2, and 3 minutes to determine uniformity of the soil flow. The tons of moist soil per hour, divided by 1 plus the moisture content expressed as a decimal, will give the tons of dry soil per hour. As shown in figure 5-24, the cement is then calibrated in a

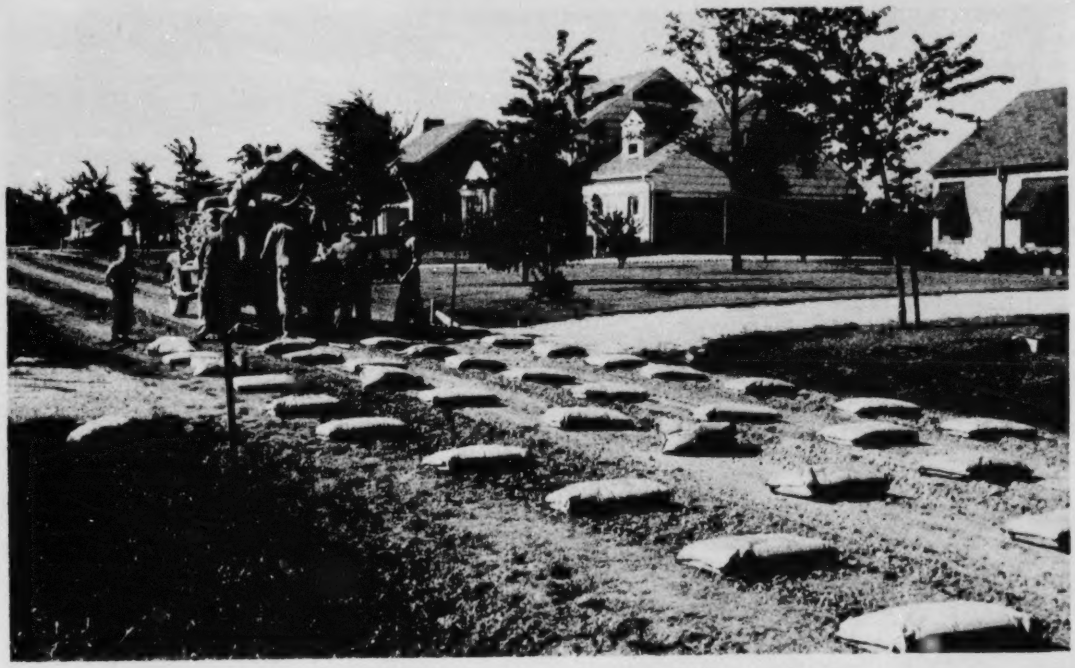

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Figure 5-22.—Spotting bags of portland cement.

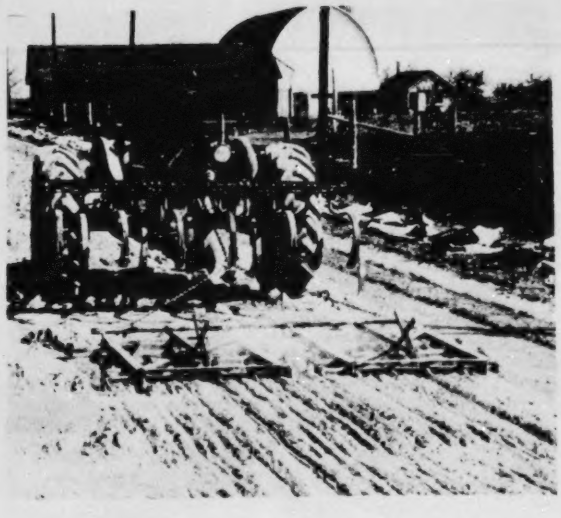

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Figure 5-23.—Using spike-tooth harrow for spreading portland cement.

similar manner by diverting it directly from the cement feeder into a truck or suitable container while soil is going through the plant. Figure 5-25 shows a diversion chute to divert cement from the cement meter to the container. The batches of soil aggregate and the cement are then weighed and the cement meter is adjusted, if necessary. The procedure is repeated until the proper proportion of cement is attained.

Rather than arbitrarily adjusting the cement feeder until the correct amount of cement is being discharged, the relationship between various feeder gate openings or revolutions per minute (depending on type of feeder) and amount of cement discharged can first be determined. By plotting this relationship, the gate openings or revolutions per minute for the required amount of cement can be determined.

When soil-cement is mixed in a batch-type plant, the proper amount of cement for each

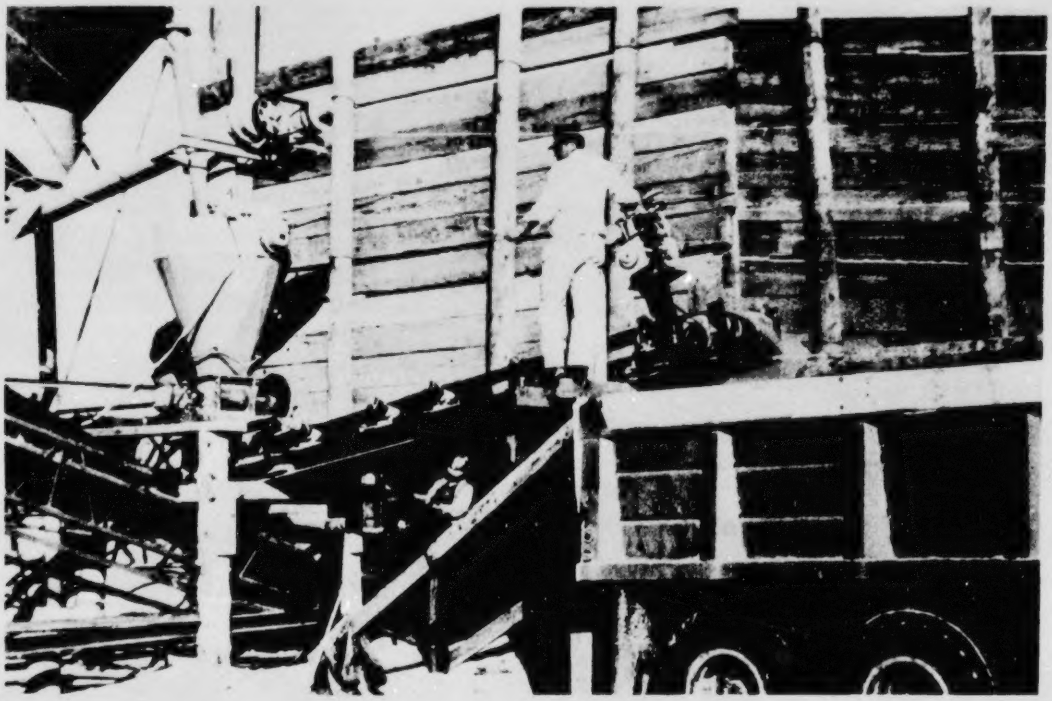

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Figure 5-24.—Calibrated cement feeder diverting cement directly into truck.

batch is weighed before being transferred to the pugmill mixer. An example of calculations for a 2,000-lb batch is given below.

Given:

Cement content, by weight of soil	5 percent
Optimum moisture content, by weight of soil plus cement	10 percent
Field moisture content of raw soil	4 percent

Procedure:

1. Proportions by percentage:

dry soil:	100.0 percent
cement:	5.0 percent
water (see note below):	
12% x (100% + 5%) =	12.6 percent
Total	117.6 percent

NOTE: Percentage of moisture required equals the optimum moisture content (10 percent) plus 2 percent to compensate for dry cement added and for evaporation.

2. Weight of dry soil:

$$\frac{2,000}{1.176} = 1,700.7 \text{ lb}$$

3. Batch weights based on dry soil:

cement:	0.05 x 1,700.7 =	85.0 lb
water:	0.126 x 1,700.7 =	214.3 lb
soil:	1.00 x 1,700.7 =	1,700.7 lb
		2,000.0 lb

4. Field moisture in soil, per batch:

0.04 x 1,700.7 = 68.0 lb

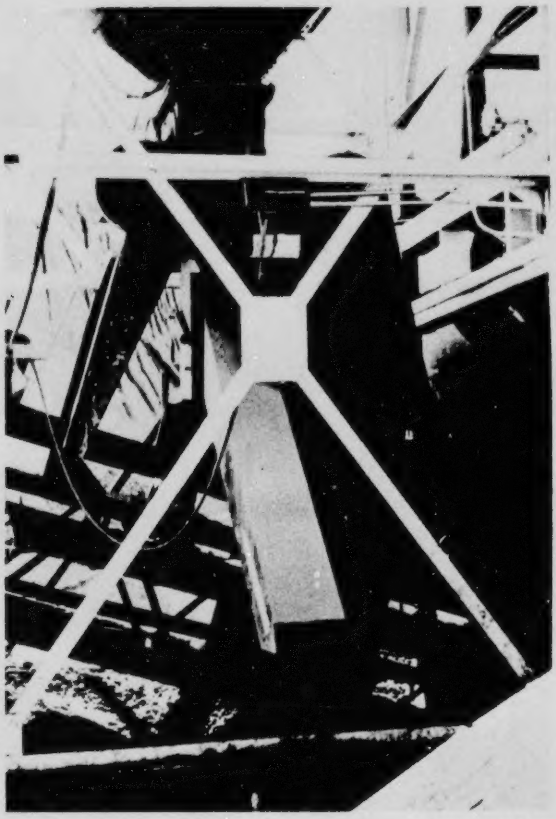

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Figure 5-25.—Diversion chute to divert cement from cement meter to a container.

5. Batch weights correct for field moisture in the soil:

cement:		85.0 lb
soil:	1,700.7 + 68.0 =	1,768.7 lb
water:	214.3 - 68.0 =	146.3 lb
	Total	2,000.0 lb

In a batch-type plant the soil and cement should be dry-mixed before water is added.

Procedures for applying water and mixing will depend upon the type of mixing machine used. A thorough mixture of pulverized soil, cement, and water must be obtained. Uniformity of the mix is easily checked by digging trenches or series of holes at regular intervals for the full depth of treatment and inspecting the color of the exposed soil-cement mixture. Uniform color and texture from top to bottom indicate a satisfactory mix; a streaked appearance indicates insufficient mixing. Proper width and depth of mixing are also important.

Windrow-type traveling mixing machines will pulverize friable soils. Other soils may need preliminary pulverizing to meet specification requirements. This is usually done before the soil is placed in the windrow and a proportioner is pulled along the windrow to make it uniform in cross-section. When borrow soils are used, a windrow spreader may be used to proportion the soil. Nonuniform windrows cause variations in cement content, moisture content, and roadway thickness. The number and size of windrows needed depend upon the width and depth of treatment and on the capacity of the mixing machine.

Cement is applied to the top of the prepared soil windrow either in bulk or by the bag. The mixing machine picks up the soil and cement, which are dry-mixed by the first few paddles in the mixing drum. At this point water is added through spray nozzles and the remaining paddles complete the mixing. The mixed soil-cement is spread with a strike-off attached to the mixing machine. (See fig. 5-26). If a motor grader spreads the mixture and a tamping roller is to be used for compaction, the mixture is first loosened with a cultivator. The material is then ready for compaction. If two windrows are being used, after mixing has progressed 350 to 500 feet along one windrow, the machine backs up and processes the other windrow for 700 to 1,000 feet.

Cement spread is kept just ahead of mixing operations. Water is supplied by tank trucks. The installation of a water tank on the mixer permits continuous operation while tank trucks are being switched. As soon as the first windrow is mixed and spread on one section of the roadway, it is compacted. While this section is being compacted, a second windrow is mixed

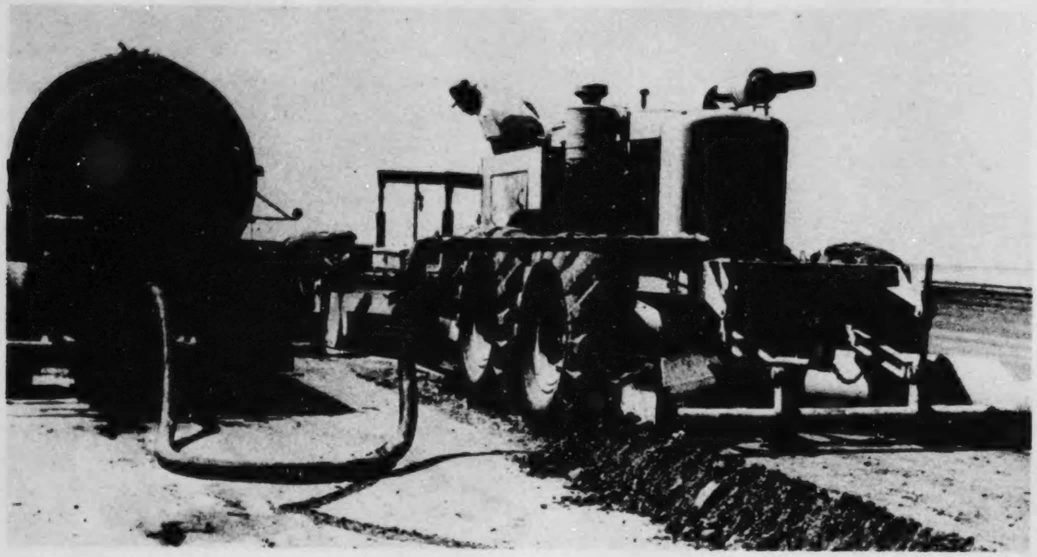

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Figure 5-26.–Strike-off attached to windrow-type mixer to level mixed soil-cement.

and spread. Then it, in turn, is compacted. The entire roadway is finished in one operation.

The water requirements are based on the quantity of soil and cement per linear foot of windrow. An example follows:

Given:

Weight of soil per linear foot of windrow	417 lb
Field moisture content of raw soil	3 percent
Optimum moisture of soil-cement mixture	10 percent
Cement content required, by weight	6 percent
Forward speed of mixing machine, approximately	12 ft. per minute

Procedure:

1. Convert the pounds of soil per linear foot of windrow at the field moisture content to oven-dry soil:

$$\frac{417}{1.03} = 405 \text{ lb oven-dry soil per foot}$$

2. Determine combined amount of soil and cement that will be processed per foot of windrow: 405 + (0.06 x 405) = 429.3 lb soil and cement per foot.

3. Calculate the gallons of water required per linear foot of windrow for 1 percent moisture:

$$\frac{0.01 \times 429.3}{8.33} = 0.52 \text{ gal per linear foot,}$$

or 1 percent moisture

NOTE: 1 U.S. gallon of water weighs 8.33 lb

4. Estimate gallons of water required per linear foot of windrow to bring mixture to required moisture (percentage of moisture required equals the optimum moisture content

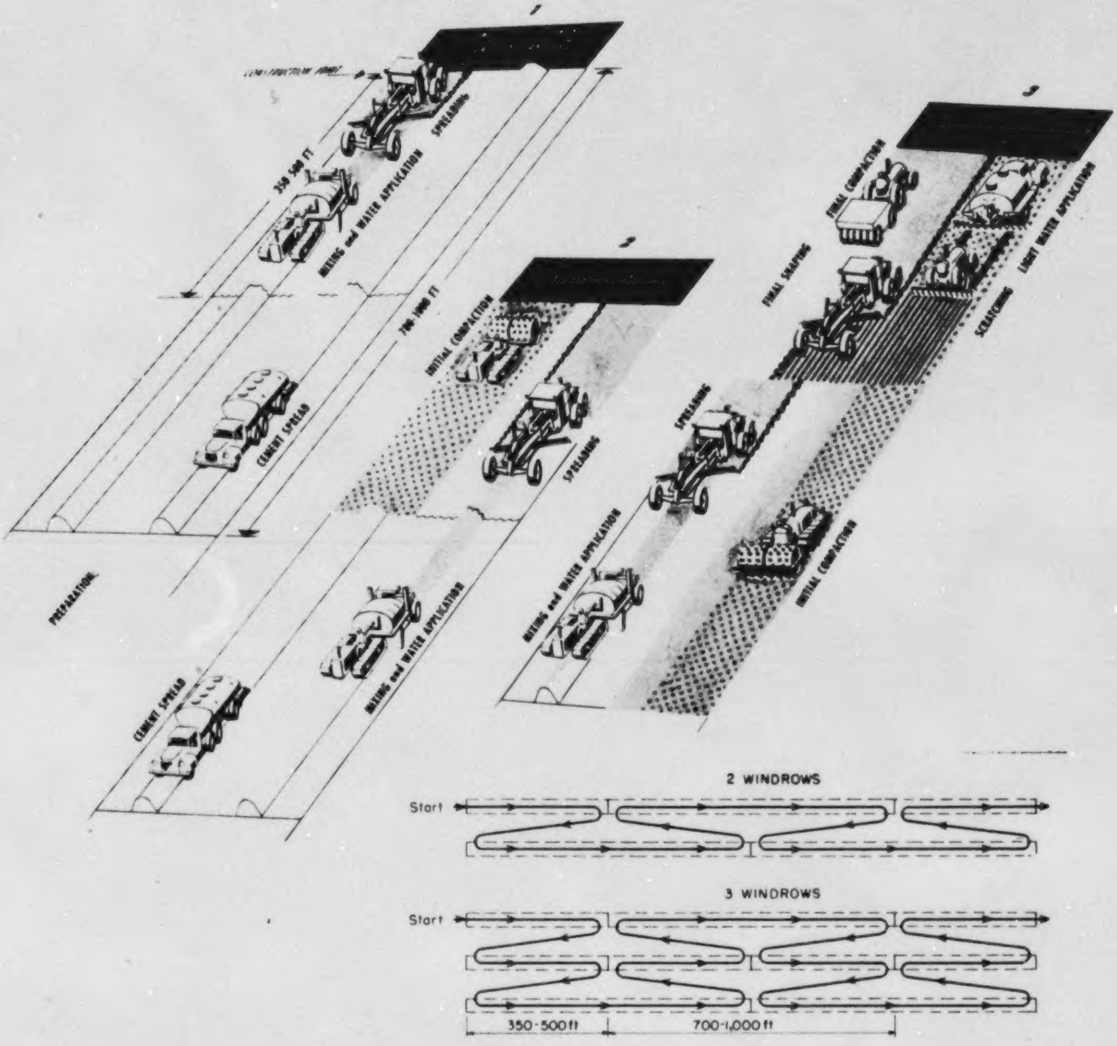
of the soil-cement mixture minus the field moisture content of the raw soil, plus 2 percent to compensate for dry cement added and for evaporation):

(10-3 + 2) x 0.52 = 4.68 gal. per linear foot

5. Determine water required per minute (12 feet per minute forward speed of mixer):

12 x 4.68 = 56 gal per minute

Construction steps and some of the equipment requirements for construction, using


1
CONSTRUCTION JOINT
SPREADING
350-500 FT
MIXING and WATER APPLICATION
CEMENT SPREAD
PREPARATION
2
INITIAL COMPACTION
700-1000 FT
SPREADING
MIXING and WATER APPLICATION
CEMENT SPREAD
3
FINAL COMPACTION
FINAL SHAPING
LIGHT WATER APPLICATION
SCARIFYING
SPREADING
MIXING and WATER APPLICATION
INITIAL COMPACTION
2 WINDROWS
Start
3 WINDROWS
Start
350-500 ft
700-1,000 ft

143.164X

Figure 5-27.—Sketch of soil-cement processing operations with windrow-type traveling mixing machine.

windrow-type traveling mixing equipment (fig. 5-27), are outlined below.

1. Construction steps to be taken in the preparation of a roadway using IN-PLACE soil:

   a. Shape roadway to crown and grade
   b. Scarify roadway soil
   c. Pulverize soil, if necessary
   d. Windrow and proportion soil

2. Construction steps to be taken in the preparation of a roadway using BORROW SOIL:

   a. Shape subgrade to crown and grade
   b. Compact subgrade
   c. Place borrow soil
   d. Windrow and proportion soil

3. Construction steps to be taken in SOIL-CEMENT processing:

   a. Apply portland cement
   b. Mix soil, cement, and water
   c. Spread mixed windrow
   d. Compact
   e. Finish
   f. Cure

4. Typical equipment requirements for PREPARATION of a roadway:

   a. 1 pulverizer, if required
   b. 1 motor grader with scarifer
   c. 1 windrow evener or spreader box

5. Typical equipment requirements for HANDLING BULK CEMENT:

   a. 1 cement transport truck
   b. 1 cement tanker with attached metering device
   c. 1 portable truck scale

6. Typical equipment requirements for MIXING and WATER application:

   a. 1 windrow-type traveling mixing machine
   b. 1 water pump at source
   c. 2 or more water supply trucks, as needed
   d. 1 motor grader

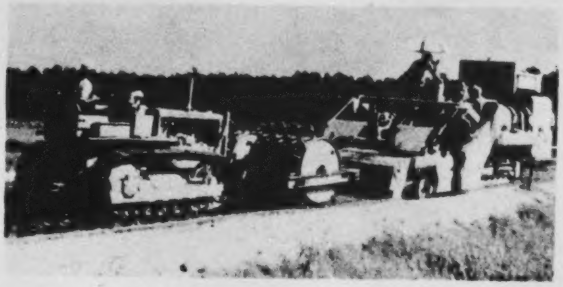


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Figure 5-28.—Multiple-shaft traveling mixing machine with compacting equipment.

Since most multiple-shaft traveling mixing machines (fig. 5-28) have a high-speed pulverizing rotor, preliminary pulverization is usually unnecessary. The only preparation required is shaping the soil to approximate crown and grade. Occasionally, an old roadbed may be extremely hard and dense, and in such cases prewetting and scarification will facilitate processing.

Processing is done in lanes 350 to 500 feet long, with a width equal to that of the machine. Cement is spread over the soil in front of the mixing machine. Either bulk cement or bag cement can be used. Cement spreading should be completed in the first working lane and under way in the second lane before mixing operations are started. This assures a full-width cement spread without a gap between lanes; also, cement-spreading equipment is out of the way of mixing equipment. The mixer picks up the soil and cement and mixes them in place. The first rotors in the mixing machine pulverize the soil and mix soil and cement. Water is measured through a meter and injected into the mix through a spray bar in the mixing chamber. The remaining rotors mix the soil, cement, and water; the mixed material is left flat on the roadway for immediate compaction. Water is supplied to the mixer by tank trucks. A small reserve water tank on the machine permits continuous operation while water trucks are being switched. After compaction, the full width of the roadway is finished in one operation.

The gallons of water required per linear foot or per minute for 1 percent moisture can be determined by using figure 5-29 as indicated in the following example.

Given: Field moisture content of
raw soil . . . . 6 percent
Laboratory optimum moisture content . . . . 14 percent
Maximum density . . . . . .100 lb per cubic foot
Compacted depth . . . . . . .6 inches
Mixing width . . . . 9 feet
Mixing rate . . . . .30 feet per minute

Procedure:

1. Percent of moisture required equals the difference between the optimum moisture content and the moisture content of the raw soil, plus 2 percent of the total mixture to compensate for dry cement added and evaporation:

   14 - 6 + 2 = 10 percent

2. Enter figure 5-29 at the left edge at 9-ft width of processing and proceed horizontally to the 6-in. depth line; then proceed vertically downward until 100-lb density line is intersected; proceed horizontally to the right and read gallons per linear foot for 1 percent moisture: approximately 0.54 gallon

3. Multiply gallons per linear foot for 1 percent moisture by the 10 percent moisture required: 10 x 0.54 = 5.4 gal per linear foot

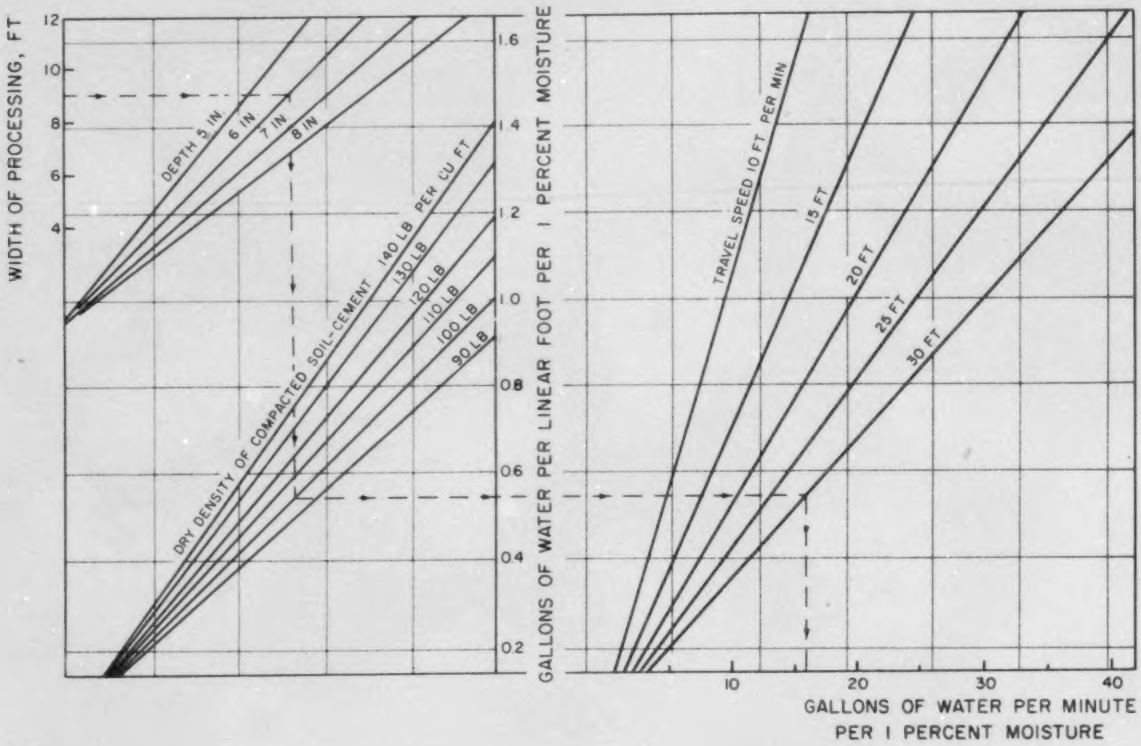

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Figure 5-29.—Water required to raise moisture content of soil-cement mixture 1 percent.

4. Continue on figure 5-29 horizontally from gallons per linear foot for 1 percent moisture until the travel speed line of 30 ft. per minute is intersected; then proceed downward and read gallons per minute for 1 percent moisture: 16.2 gallon

5. Multiply gallons per minute for 1 percent moisture by the 10 percent moisture required:

   16.2 x 10 = 162 gal per minute

Construction steps and some of the equipment requirements for construction, using multiple-shaft traveling mixing machines (fig. 5-30) are outlined below.

1. Construction steps to be taken in the preparation of a roadway using IN-PLACE soil:

   a. Shape roadway to crown and grade
   b. Loosen soil to design depth when necessary and reshape

2. Construction steps to be taken in the preparation of a roadway using BORROW soil:

   a. Shape subgrade to crown and grade
   b. Compact subgrade
   c. Place borrow soil
   d. Shape borrow soil

3. Construction steps to be taken in SOIL-CEMENT processing:

   a. Spread portland cement
   b. Mix soil, cement, and water
   c. Compact
   d. Finish
   e. Cure

4. Typical equipment requirements for PREPARATION of a roadway:

   a. 1 motor grader with scarifier

5. Typical equipment requirements for HANDLING BULK CEMENT:

   a. 1 cement conveyor
   b. 2 or more cement trucks as required
   c. 1 portable truck scale
   d. 1 mechanical cement spreader

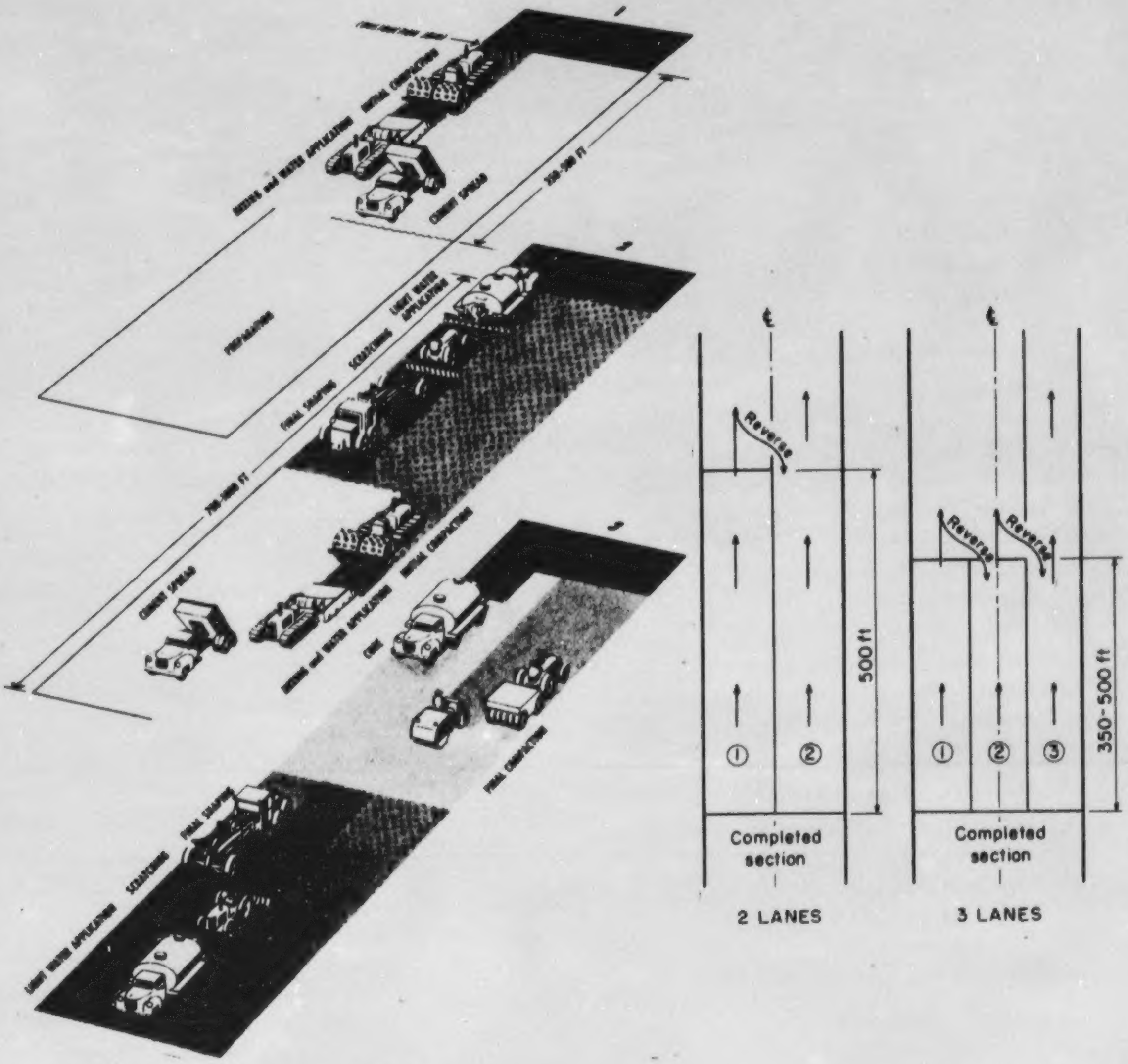
6. Typical equipment requirements for MIXING and WATER application:

   a. 1 multiple-shaft traveling mixing machine
   b. 1 water pump at source
   c. 2 or more water supply trucks, as needed

Soil-cement construction with single-shaft traveling mixers is slightly different from the preceding examples in that more than one mixing pass is usually required. The basic principles and objectives are the same however.

Shaping the roadway, scarification, and pulverization are the first steps of preparation, as described earlier. Since most single-shaft traveling mixers were not designed to scarify, the soils may need to be loosened with a scarifier. Prewetting the soil during scarification and pulverization is common practice. Applying water at this stage of construction saves time during actual processing operations because most of the required water will already have been added to the soil when cement is spread. In very granular soils, prewetting prevents cement from sifting to the bottom of the mix by causing it to adhere more readily to the sand and gravel particles. Mixing of soil and cement is easier if the moisture content of the raw soil is two or three percentage points below optimum. However, very sandy soils can be mixed even if the moisture content is one or two percentage points above optimum. Moisture should be applied uniformly during prewetting. By mixing it into the soil, evaporation losses are reduced. Because of the hazard of night rains, some prefer to do the prewetting in the early morning. After scarifying, pulverizing, and prewetting, the loose, moist soil is shaped to crown and grade.

Cement is spread by a mechanical cement spreader or from the bag.


MIXING and WATER APPLICATION
INITIAL COMPACTION
CEMENT SPREAD
PREPARATION
LIGHT WATER APPLICATION
SCARIFYING
FINAL SHAPING
CURE
FINAL COMPACTION
℄
Reverse
500 ft
①
②
Completed section
2 LANES
350-500 ft
③
3 LANES

143.167X

Figure 5-30.—Sketch of soil-cement processing operations with multiple-shaft traveling mixing machine.

Occasionally the prewet soil becomes compacted by cement-spreading equipment. In such cases, mixing may be hastened by loosening the soil again after cement is spread, usually with the scarifier on a motor grader. The scarifier teeth should be extended so that cement will flow between the teeth and not be carried forward or displaced by the scarifier frame.

The mixer picks up the soil and cement and mixes them in place. Water, supplied by a tank truck, is usually applied to the mixture by the spray bar mounted in the mixing chamber, or the water may be applied ahead of the mixer by water pressure distributors. The number of mixing passes depends on the type of soil and its moisture content and on the forward speed of the mixer.

Construction steps and some of the equipment required for construction, using single-shaft traveling mixing machines (fig. 5-31) are outlined below.

1. Construction steps to be taken in the preparation of a roadway using IN-PLACE soil:

  a. Shape roadway to crown and grade
  b. Scarify roadway soil
  c. Pulverize soil, if necessary
  d. Prewet soil, as needed
  e. Shape prepared soil

2. Construction steps to be taken in the preparation of a roadway using BORROW soil:

  a. Shape subgrade to crown and grade
  b. Compact subgrade
  c. Place borrow soil
  d. Shape borrow soil

3. Construction steps to be taken in SOIL-CEMENT processing:

  a. Spread portland cement and mix
  b. Apply water and mix
  c. Compact
  d. Finish
  e. Cure

4. Typical equipment requirements for PREPARATION of a roadway:

  a. 1 motor grader with scarifier
  b. Single-shaft mixers for pulverizing, if necessary
  c. 1 water truck with pressure spray bar for prewetting as needed

5. Typical equipment requirements for HANDLING BULK CEMENT:

  a. 1 cement conveyor
  b. 2 or more cement trucks, as needed
  c. 1 portable truck scale
  d. 1 mechanical cement spreader

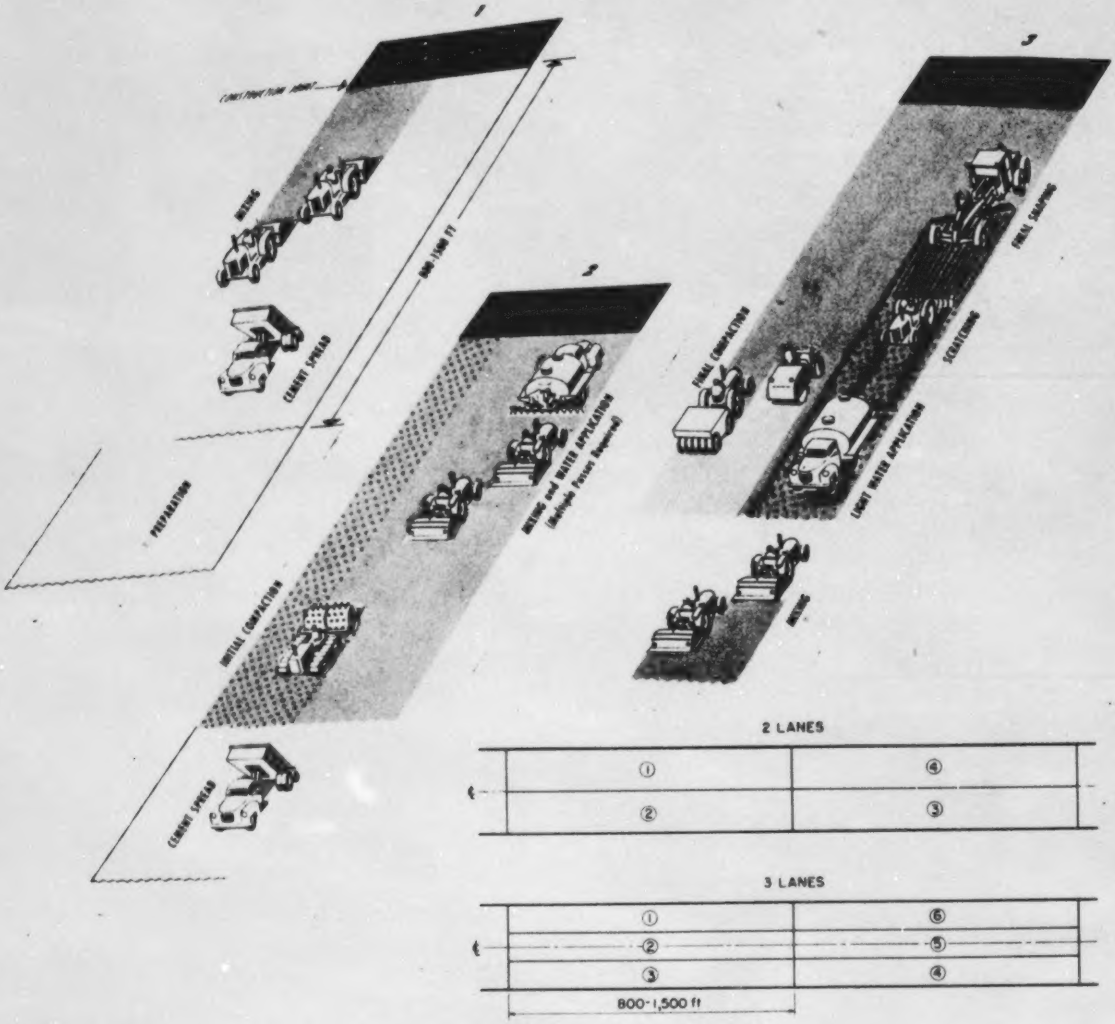
6. Typical equipment requirements for MIXING and WATER application:

  a. Single-shaft mixers (same as above)
  b. 1 water pump at source
  c. 2 or more water pressure distributors or water supply trucks, as needed

Central mixing plants are often used on projects involving borrow soils. With these plants, the same basic principles of thorough mixing, adequate cement content, proper moisture content, and adequate compaction apply. Friable granular borrow soils are generally used because of their low cement requirements and ease in handling and mixing.

Pugmill-type mixers, either of the continuous-flow or batch type, are used for this work. Generally the twin-shaft continuous-flow type is used on roadway projects. Facilities for efficiently storing, handling, and proportioning materials must be provided at the plant. Quantities of soil, cement, and water may be proportioned by volume or weight. Mixing is continued until a uniform mixture of soil, cement, and water is obtained. To reduce evaporation losses during hot, windy conditions and for the protection against sudden showers, haul trucks should be equipped with protective covers. To prevent excessive haul time, not more than 60 minutes should elapse between the start of moist mixing and start of compaction.

The mixed soil-cement is placed with mechanical spreaders. The spreader should not be allowed to "run empty" after each truckload has been discharged. Rather, the spreader should be stopped while some mix is in the hopper and until additional mix from the next truckload is entering the hopper. Dumping in piles and spreading with a motor grader should not be permitted because it produces nonuniform densities in the spread material. The mixed soil-cement should be spread to full roadway width, either by one full-width spreader or by two or more spreaders operating in a staggered position across the roadway. Less preferable is the use of one piece of spreading equipment operating one lane at a time in two or more lanes. No lane should be spread so far ahead of


1
CONSTRUCTION JOINT
MIXING
CEMENT SPREAD
800-1500 FT
PREPARATION
2
MIXING and WATER APPLICATION
(Multiple Passes Required)
INITIAL COMPACTION
CEMENT SPREAD
3
FINAL SHAPING
SCRATCHING
LIGHT WATER APPLICATION
FINAL COMPACTION
MIXING
2 LANES
①
④
℄
②
③
3 LANES
①
⑥
℄
②
⑤
③
④
800-1,500 ft

143.168X

Figure 5-31.—Sketch of soil-cement processing operations with single-shaft mixers.

the adjoining lane that a time lapse of more than 30 minutes occurs between the times of placing material in adjoining lanes at any location. The subgrade should be damp when the soil-cement is placed.

Bituminous pavers have been used for spreading soil-cement. Modification may be necessary before these machines can be used. Compacted thicknesses are usually restricted to 5 or 6 inches.

The compaction equipment should follow immediately behind the spreader. While compacting the first lane, a narrow uncompacted ridge should be left adjacent to the second lane. This serves as a depth guide when placing the soil-cement mix in the second lane. Water spray equipment should be available to keep the joint areas damp.

The amount of water needed to bring the soil-cement mixture to the required moisture content in continuous-flow-type mixing plants is based upon the amount of soil and cement coming into the mixing chamber per unit of time, as shown in the following example.

Given:

Cement content required, by weight	6 percent
Optimum moisture of soil cement mixture	10 percent
Field moisture content of raw soil	5 percent
Weight of soil (at field moisture) entering mixing drum	283.5 tons per hour

Required: Approximate gallons of water per minute.

Procedure:

1. Convert the tons of soil per hour entering the mixing drum at field moisture content to pounds of oven-dry soil per minute:

   $$\frac{283.5 \times 2{,}000}{1.05 \times 60} = 9{,}000 \text{ lb oven-dry}$$

   soil per minute.

2. Calculate quantity of cement required:

   $0.06 \times 9{,}000 = 540$ lb cement per minute.

3. Determine combined weight of soil and cement:

   $9{,}000 + 540 = 9{,}540$ lb soil and cement per minute.

4. Calculate gallons of water required per minute for 1 percent moisture:

   $$\frac{0.01 \times 9{,}540}{8.33} = 11.5 \text{ gal per minute}$$

   for 1 percent moisture.

5. Determine the approximate gallons of water required per minute to bring mixture to required moisture (percentage of moisture required equals the optimum moisture content of the soil-cement mixture minus the field moisture content of raw soil, plus 2 percent to compensate for dry cement added and for evaporation):

   $(10 - 5 + 2) \times 11.5 = 80.5$ gal per minute.

The amount of water required in batch-type central mixing plants is similarly calculated, using the weights of soil and cement for each batch. The calculations required are included in the example given previously for the batch-type mixing plant.

Construction steps and some of the equipment requirements for central mixing plant construction are outlined below.

1. Construction steps to be taken in the PREPARATION of a roadway are:

   a. Shape subgrade to crown and grade
   b. Compact subgrade

2. Construction steps to be taken in SOIL-CEMENT processing:

   a. Mix soil, cement, and water in plant
   b. Haul mixed soil-cement to roadway and spread
   c. Compact
   d. Finish
   e. Cure

3. Typical equipment requirements for PREPARATION of a roadway:

   a. Motor graders, as needed
   b. Rollers, as needed

4. Typical equipment requirements for MIXING:

   a. 1 central mixing plant, continuous-flow or batch-type, with facilities for storing, handling, and proportioning soil, cement, and water

5. Typical equipment requirements for the PLACING of material:

a. Haul trucks, as needed
b. 2 mechanical spreaders

COMPACTING

The principles governing compaction of soil-cement are the same as those for compacting the same soils without cement treatment. The soil-cement mixture at optimum moisture should be compacted to maximum density and finished immediately. Optimum moisture and maximum density are determined by AASHO and ASTM tests conducted by the EA's. Moisture loss by evaporation during compaction, as indicated by the greying of the surface, should be replaced with light applications of water.

Tamping rollers are generally used for initial compaction on all but the most granular soils. Self-propelled rubber-tired rollers (fig. 5-32) have also been used successfully on some soil-cement projects. To obtain adequate compaction, it may be necessary to operate the rollers with ballast to give greater unit pressure. The general rule is to use the greatest contact pressure that will not exceed the bearing capacity of the soil-cement mixture and that will still "walk out" in a reasonable number of passes. Friable silty and clayey sandy soils will compact satisfactorily with rollers having unit pressure of 75- to 125-psi. Clayey sands, lean clays, and silts that have low plasticity can be compacted with 100- to 200-psi rollers. Medium to heavy clays and gravelly soils require greater unit pressure—150- to 300-psi. Eight-inch compaction thickness is about the maximum that can be compacted satisfactorily with tamping rollers having standard length feet.

When tamping rollers are used for initial compaction, the mixed material must be in a loose condition at the start of compaction so that the feet will pack the bottom material and gradually "pack out" on each succeeding pass. If penetration is not being obtained, the scarifier on the motor grader or a traveling mixer may be used to loosen the mix at the start of compaction, thus allowing the feet to penetrate.

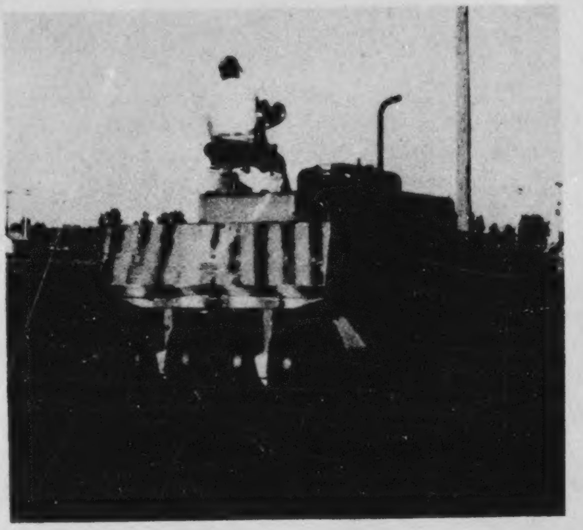


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Figure 5-32.—Self-propelled rubber-tired roller.

Vibratory compactors, vibratory rollers, grid rollers, and segmented rollers have been used satisfactorily to compact soil-cement made of nonplastic granular soils.

Pneumatic-tired rollers are used to compact coarse sand and gravel soil-cement mixtures having very little or no plasticity and very sandy mixtures containing little or no binder material, such as dune, beach, or blow sand.

Self-propelled pneumatic rollers are very versatile and efficient. Recent introduction of a device that permits rapid inflation and deflation of the tires while compacting further increases their versatility.

Pneumatic-tired rollers pulled by track-type tractors equipped with street plates are commonly used to compact cohesionless sand mixtures (fig. 5-33). The weight and vibration of the tractor aid in compaction.

Twelve-ton, three-wheel steel rollers are commonly used in some areas to compact granular soils containing little or no binder material. Gravelly soils that contain up to about 20 percent material passing the No. 200 sieve and have low plasticity are best suited for compaction with these rollers.

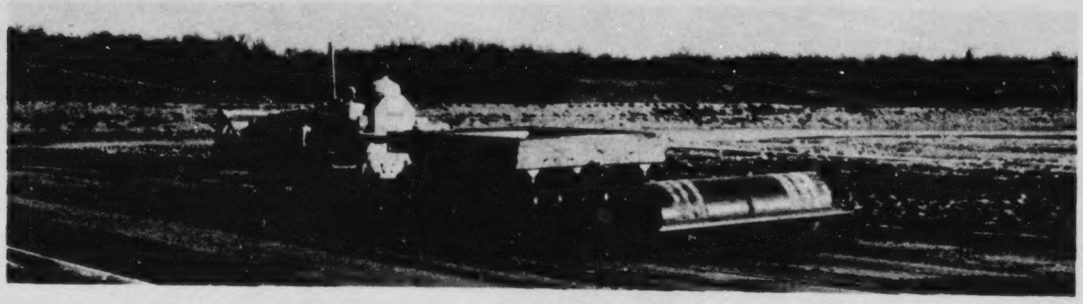

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Figure 5-33.–Pneumatic-tired roller pulled by track-type tractor equipped with street plates.

Tandem steel-wheel rollers (fig. 5-34) are often used during final rolling to press down or "set" rock particles and smooth out the ridges.

There are two general types of road cross-section: trench and featheredge. Both can be built satisfactorily with soil-cement. In trench-type construction the shoulder material gives lateral support to the soil-cement mixture during compaction. With the featheredge type of construction, the edges are compacted first to provide some edge stability while the remaining portion is being compacted. The edge slope should not be steeper than 2:1 to facilitate shaping and compacting. Shoulder material is placed after the soil-cement has been finished.

Occasionally during compaction and finishing a localized area may yield under the compaction equipment. This may be due to one or more of the following causes: (1) the soil-cement mix is much wetter than optimum moisture; (2) the subsoil may be wet and unstable; or (3) the roller may be too heavy for the soil. If the soil-cement mix is too damp, it should be aerated with a cultivator, traveling mixer, or motor grader. After it has dried to near optimum moisture, it is compacted.

For best results, compaction should start immediately after the soil, cement, and water have been mixed. Required densities are then obtained more readily; there is less water evaporation; and daily production is increased. Minimum density requirements for soil-cement range from 95 to 100 percent of the maximum density as determined by a representative field sample taken by the EA's. Excess densities are beneficial.

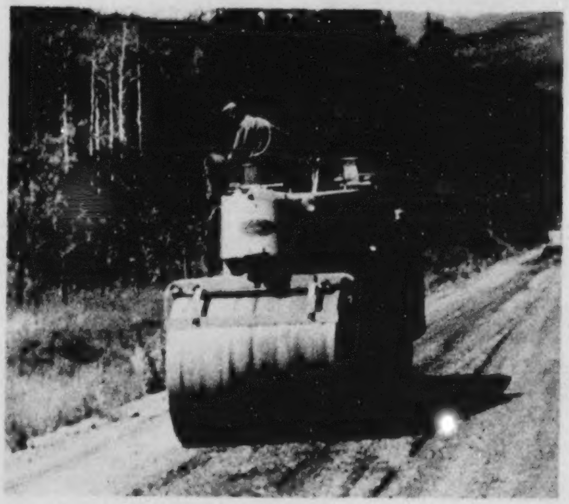

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Figure 5-34.–Three-axle, tandem steel-wheel roller.

FINISHING

There are several acceptable methods of finishing soil-cement. The exact procedure depends upon the equipment, job conditions, and soil characteristics. Some of the types of equipment used in finishing are illustrated in figures 5-35 through 5-38. To produce a high-quality surface it is important that the

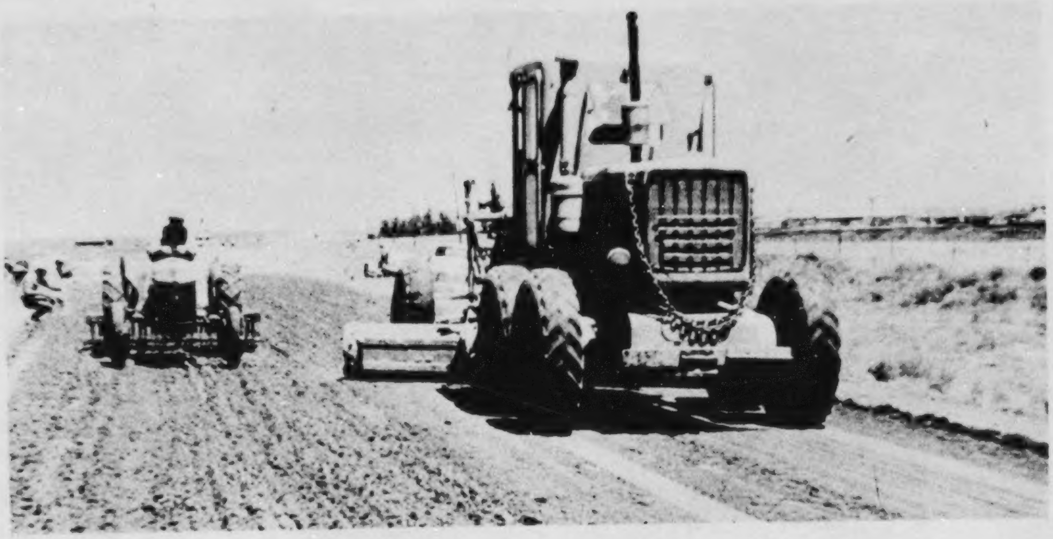

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Figure 5-35.—Scratcher removing smooth areas left by motor grader.

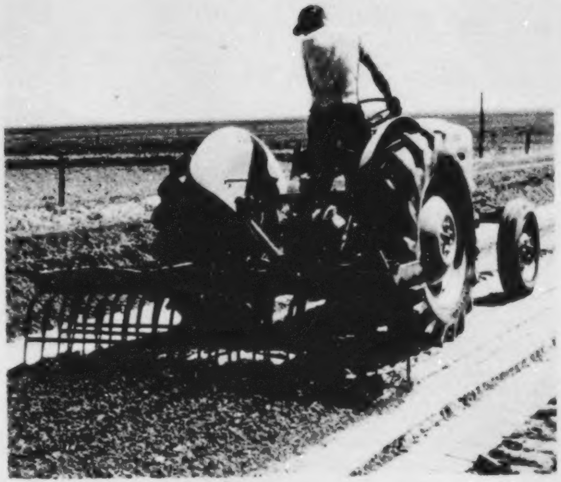

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Figure 5-36.—Hydraulically controlled weeder removing smooth areas left by motor grader.

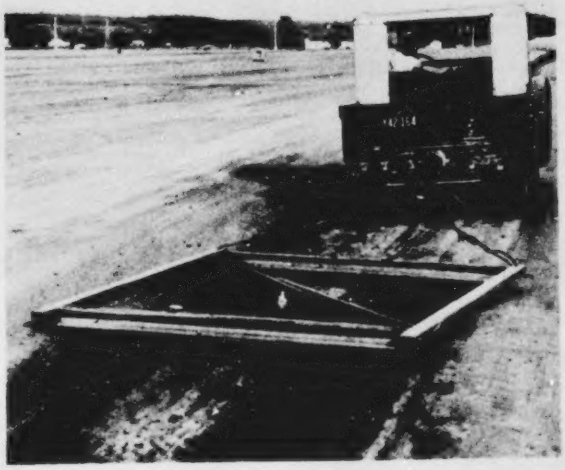

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Figure 5-37.—A broom drag used to produce smooth surface finish.

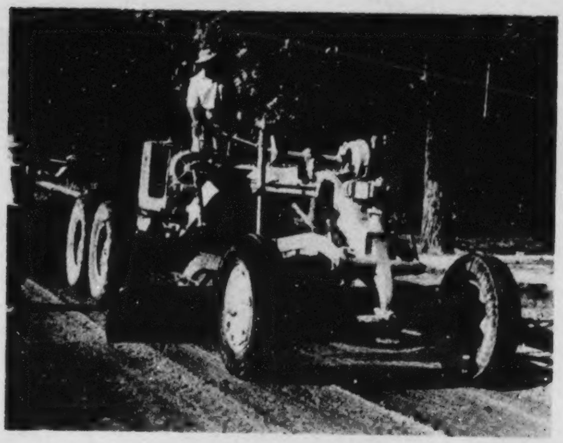

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Figure 5-38.–Motor grader shaves the surface.

fundamental requirements of adequate compaction, close to optimum moisture, and removal of all surface compaction planes (smooth areas left near the surface by wheels of equipment, motor graders, or tamping roller feet) must be met to produce a high quality surface. The surface should be smooth, dense, and free of ruts, ridges, or cracks.

When shaping is done during finishing, all smooth surfaces, such as tire imprints and blade marks, should be lightly scratched with a weeder, nail drag, coil spring, or spiketooth harrow to remove cleavage or compaction planes from the surface. The surface should be kept damp during finishing operations. Steel-wheel rollers can be used to smooth out ridges left by initial pneumatic-tired rollers. These rollers are particularly advantageous when rock is present in the surface. A broom drag is sometimes used advantageously to pull binder material in and around pieces of gravel that have been "set" by the steel-wheel roller. In lieu of using a steel roller, surfaces are commonly shaved with the motor grader and then rerolled with a pneumatic-tired roller to seal the surface. Shaving consists of lightly cutting off any small ridges left by the finishing equipment. Only a very thin depth is cut and all material removed is bladed to the edge of the roadway and wasted. The final operation usually consists of a light application of water and rolling with a pneumatic-tired roller to seal the surface. The finished soil-cement is then cured.

Outlines of several methods used for finishing soil-cement follow. All will produce satisfactory compaction and surface finish if the fundamentals are adhered to.

Method 1. Finishing procedure for most soil-cement mixtures compacted with tamping roller.

a. Remove compaction planes with weeder, nail drag, coil spring, or spike-tooth harrow while shaping with motor grader. A drag broom is sometimes used to line ridges and a light application of water is applied as needed.
b. Roll with pneumatic-tired roller.
c. Scalp with motor grader, then use drag broom if necessary.
d. Roll with pneumatic-tired roller, using a light application of water as needed. In some instances, a tandem steel-wheel roller is used prior to final rolling with the pneumatic-tired roller.

Method 2. Finishing procedure for mixtures, compacted with tamping roller, that contain appreciable quantities of gravel and have little or no plasticity.

a. Shape with motor grader.
b. Roll with steel-wheel roller.
c. Use broom drag.
d. Roll with pneumatic-tired roller, using a light application of water as needed.

Method 2a. Alternate for Method 2. This method is recommended for granular mixtures containing appreciable quantities of gravel; it is recommended for other soil-cement mixtures.

a. Shape with motor grader, using a light application of water as needed.
b. Roll with steel-wheel roller.
c. Use broom drag over section.
d. Roll with pneumatic-tired roller, using a light application of water as needed.

Method 3. Finishing procedure for very sandy mixtures containing little or no fines—such as cohesionless dune or blow sand containing 0 to 10 percent minus No. 200 sieve material—and compacted with pneumatic-tired roller pulled by track-type tractor with street plates.

a. Remove compaction planes with weeder, nail drag, coil spring, or spike-tooth harrow while shaping with motor grader; also, use a light application of water as needed.
b. Roll with pneumatic-tired roller and drag with broom.
c. Scalp with motor grader, using a light application of water as needed.
d. Use drag broom.
e. Roll with pneumatic-tired roller and use a light application of water as needed.

Method 4. Finishing procedure for coarse granular mixtures (not blow sands) containing up to 20 percent material passing the No. 200 sieve with a low P.I. (plasticity index) and compacted with a three-wheel, 12-ton steel roller.

a. Scalp high areas with motor grader.
b. Roll with pneumatic-tired roller, using a light application of water as needed.

JOINT CONSTRUCTION

At the end of each day's construction a transverse vertical construction joint is formed by cutting back into the completed soil-cement to the proper crown and grade. This is done usually the last thing at night or the first thing the following morning, using the toe of the motor grader blade (fig. 5-39) or hand axes.

After the next day's mixing has been completed at the joint, it is cleaned of all dry and unmixed material and retrimmed if necessary. Mixed moist material is then bladed into the area and compacted thoroughly. During this stage of construction the joint is left slightly high; during final rolling it is trimmed to grade with the motor grader and rerolled.

MULTIPLE-LAYER CONSTRUCTION

Where the specified thickness of a soil-cement base course exceeds the depth (usually 8 inches compacted) that can be thoroughly mixed, moistened, compacted, and finished in one layer, it is constructed in multiple layers. No layer should be less than 4 inches thick. The lower layer does not have to be finished to exact crown and grade, nor do surface compaction planes have to be removed since they are too far from the final surface to be harmful. The lower layer can be cured with moist soil that is subsequently used to build the top layer, which may be built immediately, the following day, or some time later.

CURING

Compacted and finished soil-cement contains sufficient moisture for adequate cement hydration. A moisture-retaining cover is placed over the soil-cement soon after completion to retain this moisture and permit the cement to hydrate. Most soil-cement is cured with bituminous material, but other materials, such as waterproof paper, plastic sheets, wet straw or sand, or wet burlap or cotton mats are entirely satisfactory.

At the time of application, the soil-cement surface should be free of all dry, loose, and extraneous material. The bituminous materials are applied to a moist soil-cement surface. In most cases water is applied immediately ahead of the bituminous application. When traffic is to be maintained, the bituminous material is sanded to prevent its pickup by traffic.

Traffic in small volume can be handled through the construction area. If side ditches or shoulders are flat, traffic can be diverted to these areas. In extreme cases, where traffic volume is large and detours are not feasible, half-width construction may be employed, but this is not the best practice since a longitudinal construction joint must be built. Loads of less magnitude than that of the equipment used in building the soil-cement will not harm the

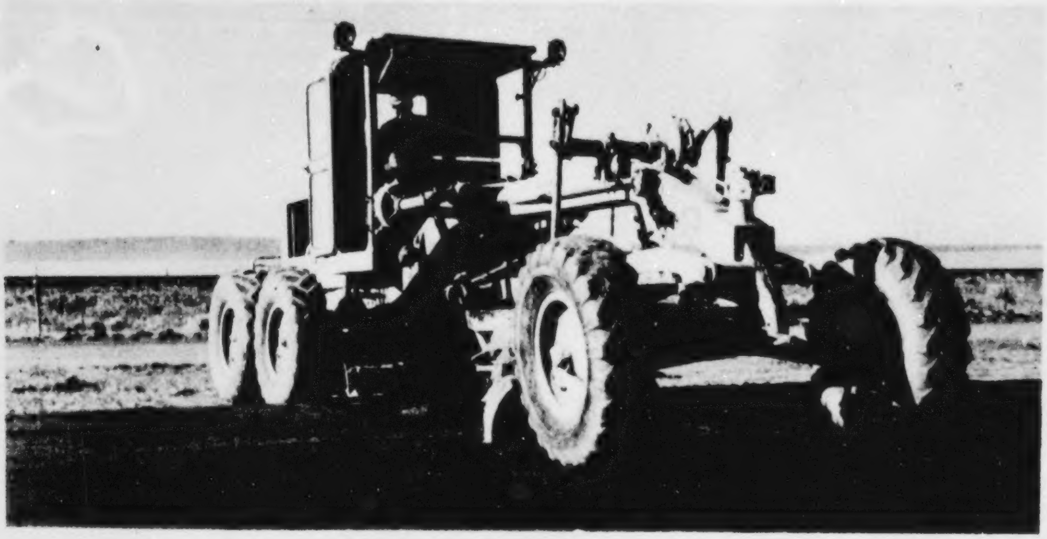

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Figure 5-39.—Grader cutting a vertical transverse construction joint.

freshly constructed base provided the subgrade is stable. Traffic should be controlled since high-speed traffic may mar the "green" surface. If traffic is to be maintained, provisions should be made to keep the curing material in place.

Soil-cement, like other cement-using products, hardens as the cement hydrates. Since cement hydration practically ceases when temperatures are near or below freezing, soil-cement should not be placed when the temperature is 40°F or below. Moreover, it should be protected to prevent its freezing for a period of 7 days after placement, and until it has hardened, by a suitable covering.

A bituminous surface should be placed on the completed soil-cement base course as soon as practical. Although it is not unusual for several weeks to elapse between the completion of the soil-cement and placement of the wearing course, it may be placed immediately if necessary.

The type and thickness of surfacing depend on traffic volume, availability of materials, cost, and local practices. In general, the thickness of the wearing course necessary on soil-cement base course will be less than required on a granular-type base. A common type of wearing course for lightly traveled roads and airstrips is a double surface treatment about 3/4 inch thick. As traffic volumes increase, thicker, high-quality surfacings are warranted. Where snow plows are likely to be used, a minimum of 1 1/2 inches of bituminous surface is commonly employed. A minimum 1 1/2-inch bituminous surface is also recommended for soil-cement shoulders in frost areas to provide protection against snow plow damage and is also a common type of wearing course for airfields where the volume of traffic or type of aircraft warrants its use.

Local experience and practice will dictate the specific details of construction. Good construction practices such as thorough cleaning of the base course should always be followed when the surfacing is placed.

There are special uses of soil-cement where bituminous surfaces are not justified. If the soil-cement is to be left unsurfaced, the cement factor should be increased to provide additional abrasion resistance. This increase should be 2 percent for granular soils containing less than 50 percent silt and clay and 4 percent for other soils.

BITUMINOUS SURFACING MATERIALS

Instead of soil-cement, bituminous materials are used on the construction of paved roads and runways. The common bituminous surfacing materials are asphalt cements, asphalt cutbacks, asphalt emulsions, road tars, and road tar cutbacks. For identification purposes, these materials are divided into three classes: asphalt bitumens, emulsions, and tars. The classification is based on the extent to which they dissolve in a distillate of petroleum or coal. Asphalt cements and asphalt cutbacks are asphalt bitumens (or asphalts). Road tars and road tar cutbacks are tars.

ASPHALT CEMENTS

Asphalt cements are solid products of petroleum refining. An asphalt cement is designated by the letter symbol AC, followed by the number that represents its relative solidity. This number ranges from 40 (hard) to 300 (soft). It is derived from a penetration test in which the solid asphalt cement is penetrated with a needle. The distance that the needle penetrates the asphalt cement is a measure of relative solidity.

ASPHALT CUTBACKS

An asphalt cutback is asphalt cement that has been mixed with (or cut back by) a petroleum distillate which affects the curing rate of the bitumen. Curing rate is a measure of the speed with which the asphalt cutback hardens, after application, to the point where the pavement may be used. A set of letter symbols (RC, MC, and SC) indicates the curing rates of asphalt cutbacks and the kinds of distillates used in the process of cutting back. Respectively, the symbols stand for rapid curing, medium curing, and slow curing. The curing rate is rapid (RC) when the distillate is naphtha or gasoline. Using kerosene as the distillate slows the curing rate to medium (MC). When fuel oil is the distillate, the curing rate is slow (SC).

Viscosity grade is a measure of the relative consistency of an asphalt bitumen after cutterstock is added to a fixed amount of it. The grade is designated by a number that corresponds to the lower limit of the viscosity of asphalt cutback as determined by a standard test. The upper limit of viscosity is defined as twice the lower limit. The units of measure are centistokes. The viscosity grades of RC, MC, and SC are 70 (70-140), 250 (250-500), 800 (800-1600), and 3,000 (3,000-6,000). The numbers in parentheses are the lower and upper limits of viscosity. In addition, MC has a grade 30 (30-60). The grades range from 30 (most fluid) to 3,000 (least fluid).

ASPHALT EMULSIONS

An asphalt emulsion is a nonflammable liquid substance, produced by combining asphalt cement and water with an emulsifying agent, such as soap or a special colloidal clay or dust. This agent helps keep the asphalt cement suspended in the water and controls certain physical properties of the emulsion. When the emulsion is applied to a surface, the water and asphalt cement break (separate), leaving a thin film of asphalt cement. The speed of separation, referred to as setting rate, is the basis for designating an asphalt emulsion. The setting rates are rapid, medium, and slow. The letter symbols for these rates are RS, MS, and SS, respectively.

As shown in table 5-5, two basic kinds of asphalt emulsions have been established according to whether they are negatively or positively charged. Moreover, they are graded on the basis of viscosity and grouped according to usage. The viscosity grades range from 1 (least fluid) to 3 (most fluid). The use of ANIONIC or negatively charged emulsions has been somewhat

Table 5-5.—Asphalt Emulsions According to Their Electric Charge

Kind	Type	Viscosity Grade	Mixing Ability
Anionic	RS	RS-1, RS-2	Spraying
	MS	MS-2	Mixing and spraying
	SS	SS-1, SS-1h	Mixing and spraying
Cationic	RS-C	RS-2C, RS-3C	Spraying
	MS-C	SM-C	Mixing (sand) and spraying
	MS-C	CM-C	Mixing (coarse aggregate) and spraying
	SS-C	SS-C, SS-Ch	Mixing and spraying

Note: C–denotes cationic emulsion.
h–denotes a lower penetration grade of asphalt cement.

restricted in the past since they did not adhere easily to negatively charged aggregates. However, certain CATIONIC or positively charged emulsions will adhere more easily to the negatively charged aggregates.

TARS

Tar is extracted from coal. A road tar is designated by the symbol RT, a viscosity grade number. Viscosity grades range from 1 through 12. RT-1, RT-2, and RT-3 are called PRIMING OILS. RT-4 through RT-7 are called COLD TARS, because they are fluid enough to be mixed and applied at relatively low temperatures. RT-8 through RT-12 are called HOT TARS, because they are solid enough to require high temperatures for mixing and applying.

The symbol RTCB refers to ROAD TAR CUTBACKS, which are manufactured only in viscosity grades 5 and 6. Coal distillate, such as benzene or a solution of naphtalene in benzol, may be used to cut back the heaviest grades of road tar to produce both grades of road tar cutbacks. The viscosity grades of road tars and road tar cutbacks can be compared to the viscosity grades of asphalt cutbacks and asphalt cement by means of table 5-6.

USE OF BITUMINOUS MATERIALS

Selection of a particular bituminous material depends upon the type of pavement, climatic conditions, seasonal factors, and availability of equipment.

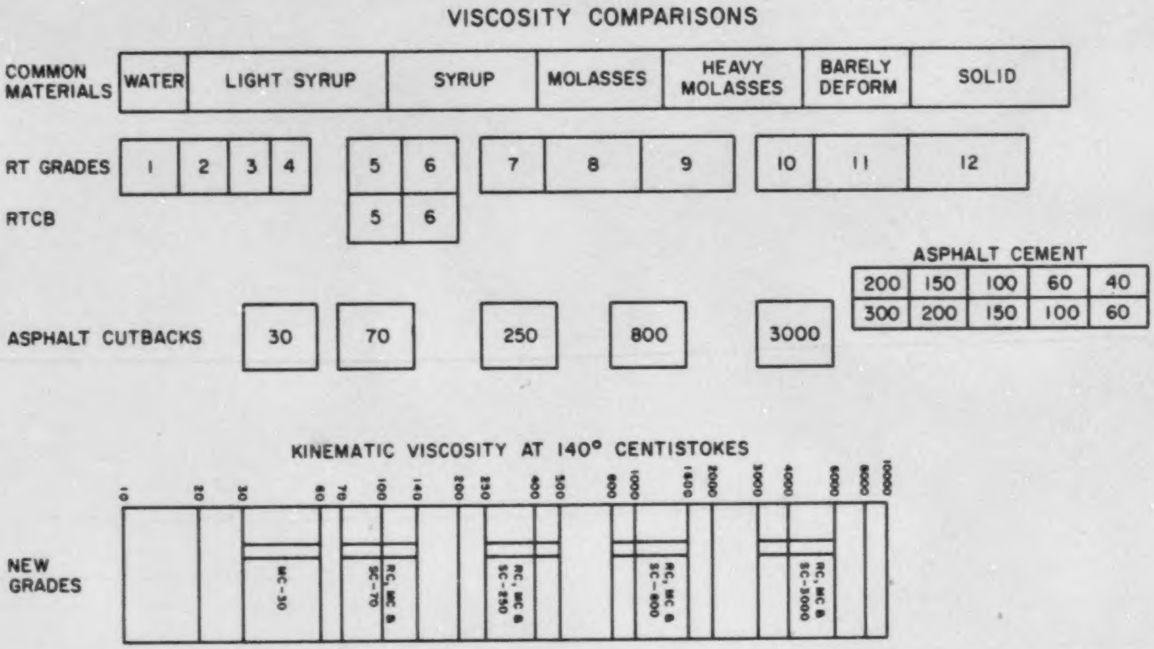
ASPHALT CEMENT

Asphalt cement is the most satisfactory bitumen for pavements. It is a semisolid at room temperature of 77°F. To make it fluid enough for mixing with aggregate or for spraying, asphalt cement must be heated to a temperature ranging from 250°F to 350°F, depending upon the grade of the asphalt cement. A disadvantage of asphalt cement is that adequate heating equipment may not always be available. The various penetration grades are suitable for different uses, including plant mixes, penetration macadam, and surface treatment. In general, soft penetration grades of asphalt cement are preferred for use in cold climates, medium grades in moderate climates, and hard grades in warm climates.

ASPHALT CUTBACKS

Different types and grades of asphalt cutbacks may be used with various climatic

Table 5-6.—Viscosity Grades at Room Temperature


VISCOSITY COMPARISONS
COMMON MATERIALS
WATER
LIGHT SYRUP
SYRUP
MOLASSES
HEAVY MOLASSES
BARELY DEFORM
SOLID
RT GRADES
1
2
3
4
5
6
7
8
9
10
11
12
RTCB
5
6
ASPHALT CEMENT
200
150
100
60
40
300
200
150
100
60
ASPHALT CUTBACKS
30
70
250
800
3000
KINEMATIC VISCOSITY AT 140° CENTISTOKES
10
20
30
60
70
100
140
200
250
400
500
800
1000
1400
2000
3000
4000
6000
8000
10000
NEW GRADES
MC-30
RC, MC & SC-70
RC, MC & SC-250
RC, MC & SC-800
RC, MC & SC-3000

82.212

conditions for different types of pavement. The cutterstock evaporates, leaving asphalt cement as the active binding and waterproofing agent. Prevailing atmospheric temperature during construction is a factor that must be considered in selecting the grade of asphalt cutback. The heavier grades are preferred for use in warm weather; the lighter grades in cool weather. If the preferred grade of a given type of asphalt cutback is not available, a comparable grade of another type may be substituted. For example, RC-800 may be used instead of MC-800, or RC-70 instead of MC-70, without seriously affecting the finished pavement. Light grades of asphalt cutback may be produced in the field by adding solvents to asphalt cutback. The composition of asphalt cutbacks, expressed in percent of total volume, is shown in table 5-7.

ASPHALT EMULSIONS

Emulsions are used for surface treatment, road and plant mixes, and crack and joint filling. The mixing grades can be mixed unheated with damp aggregate and are preferred over the asphalt cutbacks when the aggregate is very damp. Cationic emulsions will coat damp aggregate better than anionic emulsions will. Recommended usage depends on setting rate and mixing ability. At water-freezing temperatures, asphalt emulsions do not mix well since the emulsion will separate from the water. Also, emulsions are difficult to store or stockpile as they tend to break while still in their unopened drums.

TARS

Tars do not strip easily from the aggregate in the presence of water; they are preferred for prime coats. Because they will not dissolve in petroleum distillates, tars are also suitable for use on areas where asphalt is unsuitable, such as

Table 5-7.–Asphalt Cutback Composition (Expressed in Percent of Total Volume)

Type	Components		Grades				
		Solvent	30	70	250	800	3000
Rapid Curing RC	Asphalt Cement		------	65	75	83	87
		Gasoline or Naphtha	------	35	25	17	13
Medium Curing MC	Asphalt Cement		54	64	74	82	86
		Kerosene	46	36	26	18	14
Slow Curing SC	Asphalt Cement		------	50	60	70	80
		Fuel Oil	------	50	40	30	20

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a refueling apron on an airfield where petroleum distillates are likely to be spilled. In addition, tars penetrate more deeply into the base course than asphalt of the same viscosity and curing rate. Cold tar mixes are used for road mix and patching; hot tar mixes for plant mix, surface treatment, penetration macadam, crack-fillers, and similar uses. Since tars become soft at high temperatures and brittle at low temperatures, the heavier grades are preferred in warm weather and the lighter grades in cool weather.

Road tar cutbacks are used for patching mixes. However, an open flame must not be used near storage tanks and drums of road tar cutbacks because they are flammable.

FIELD IDENTIFICATION OF BITUMINOUS MATERIALS

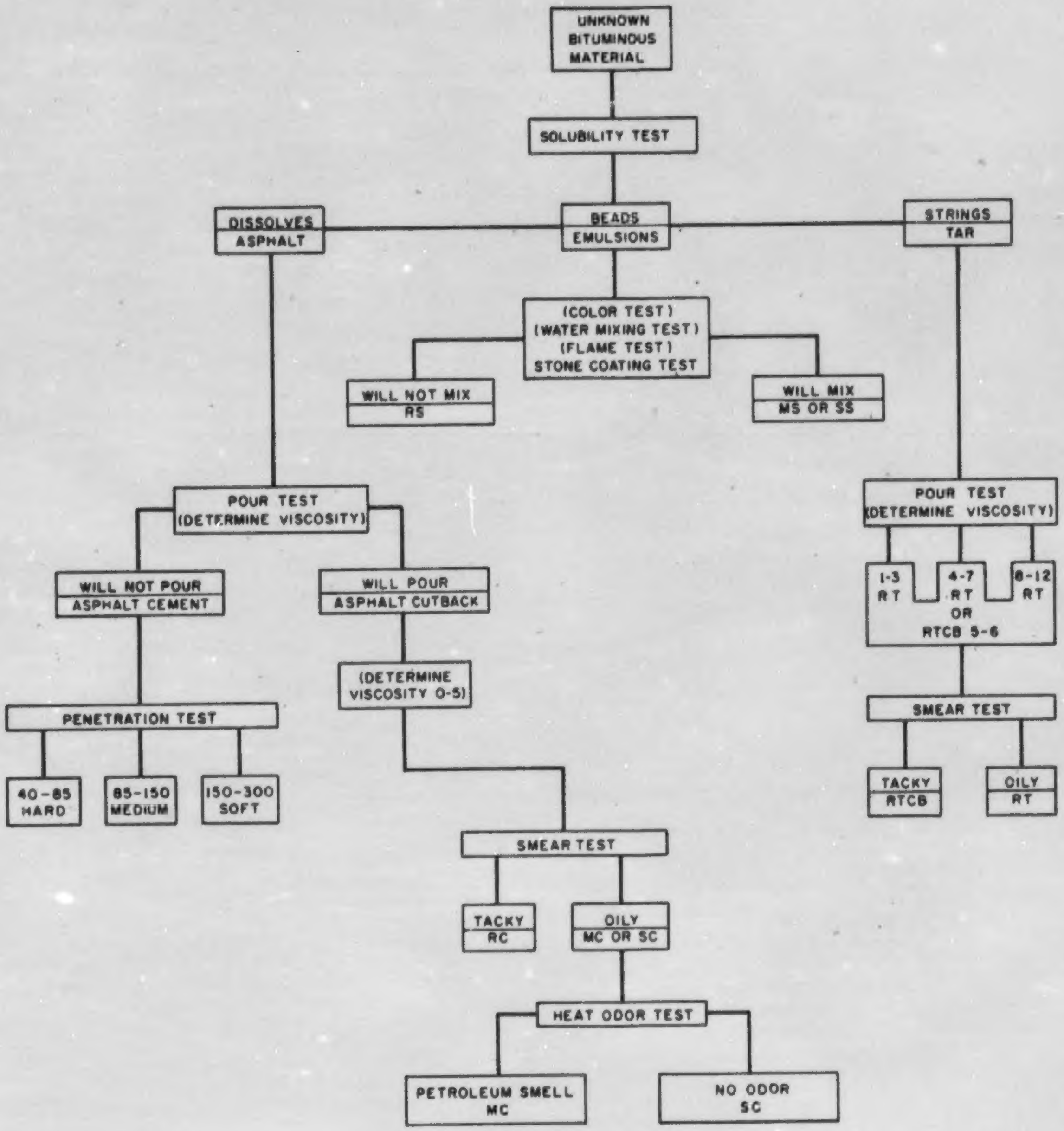
Bituminous materials are often found stockpiled in unmarked or incorrectly marked containers. Fairly accurate identification is necessary to decide on the type of construction, the method of construction, the type and quantity of equipment, and applicable safety regulations. Field tests must be performed to identify the bituminous material as asphalt cement, asphalt cutback, asphalt emulsion, road tar, or road tar cutback, and to identify the grade. Field identification of bituminous materials is summarized in figure 5-40. Tests conducted in the field include solubility, pour, penetration, smear, heat-odor, water-mixing, flame, and stone-coating tests.

SOLUBILITY TESTS

The first step in the identification of an unknown bituminous material is to determine whether it is an asphalt, an emulsion, or a tar. Bituminous materials may be differentiated by a simple solubility test. To perform the test, dissolve an unknown sample (a few drops, if liquid, or enough to cover the head of a nail, if solid) in any petroleum distillate. Kerosene, gasoline, diesel oil, or jet fuel is suitable for this test; one or more of these is usually available to the EO in the field. Since asphalt is derived from petroleum, it will dissolve in the petroleum distillate. An emulsion can be detected by the appearance of small black globules, or beads, which fall to the bottom of the container. Road tar will not dissolve. If the sample is an asphalt, the sample-distillate mix will consist of a dark, uniform liquid. If it is a road tar, the sample will be a dark, stringy, undissolved mass in the distillate. A check can be made by spotting a piece of paper or cloth with the mix. The solubility test provides a positive method of identification. See figure 5-41.

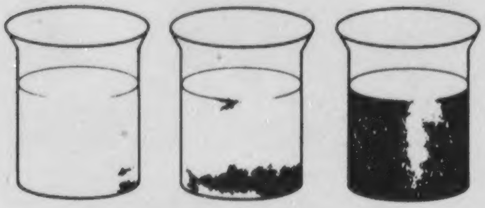
TESTS FOR ASPHALT CEMENT

If the bituminous material has been identified as an asphalt, a POUR TEST is used to

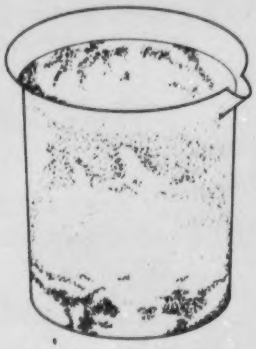

UNKNOWN BITUMINOUS MATERIAL
SOLUBILITY TEST
DISSOLVES
ASPHALT
BEADS
EMULSIONS
STRINGS
TAR
(COLOR TEST)
(WATER MIXING TEST)
(FLAME TEST)
STONE COATING TEST
WILL NOT MIX
RS
WILL MIX
MS OR SS
POUR TEST
(DETERMINE VISCOSITY)
WILL NOT POUR
ASPHALT CEMENT
WILL POUR
ASPHALT CUTBACK
(DETERMINE VISCOSITY 0-5)
PENETRATION TEST
40-85
HARD
85-150
MEDIUM
150-300
SOFT
SMEAR TEST
TACKY
RC
OILY
MC OR SC
HEAT ODOR TEST
PETROLEUM SMELL
MC
NO ODOR
SC
POUR TEST
(DETERMINE VISCOSITY)
1-3
RT
4-7
RT
OR
RTCB 5-6
8-12
RT
SMEAR TEST
TACKY
RTCB
OILY
RT

82.205

Figure 5-40.—Field identification of unknown bituminous materials.



FROM LEFT TO RIGHT: KEROSENE, KEROSENE PLUS TAR, KEROSENE PLUS ASPHALT CEMENT OR ASPHALT CUTBACK.



BEADS FORMED BY ASPHALT EMULSION IN KEROSENE.

143.178

Figure 5-41.—Solubility test for asphalt, tar, and emulsion.

distinguish asphalt cement from asphalt cutback. To perform this test, a small sample of asphalt is placed in a container at room temperature of 77°F. Asphalt cement is a solid at room temperature, and will not pour. Even the highest penetration grade (200 to 300) will not pour or immediately deform.

The various grades of asphalt cement are distinguished principally by their hardness, as measured by a PENETRATION TEST. For purposes of field identification, the consistency of asphalt cement may be approximated at room temperature as hard, penetration 40-85; medium, penetration 85-150; and soft, penetration 150-300. These limitations are flexible, as complete accuracy is not essential. An approximation of the hardness may be made in the field by attempting to push a sharpened pencil or nail into the asphalt at 77°F, with a firm pressure of approximately 10 pounds. When the pencil point penetrates with difficulty or breaks, the asphalt cement is hard. When it penetrates slowly with little difficulty, the asphalt cement is medium. If the pencil penetrates easily, the asphalt cement is a high penetration grade or soft.

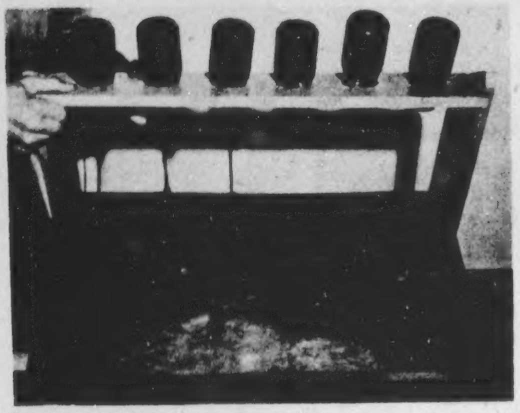
TESTS FOR ASPHALT CUTBACKS

In addition to distinguishing asphalt cement from asphalt cutback, the pour test can determine the approximate viscosity grade of the cutback. At room temperature (77°F), even the thickest asphalt cutback will start pouring in 13 seconds, as shown in figure 5-42. To approximate the viscosity grade of an asphalt cutback, remember that grade 30 pours like light syrup, grade 70 like syrup, grade 250 like molasses, and grade 800 like heavy molasses. Also, grade 3,000 will barely deform. Viscosity comparisons are given in table 5-6.

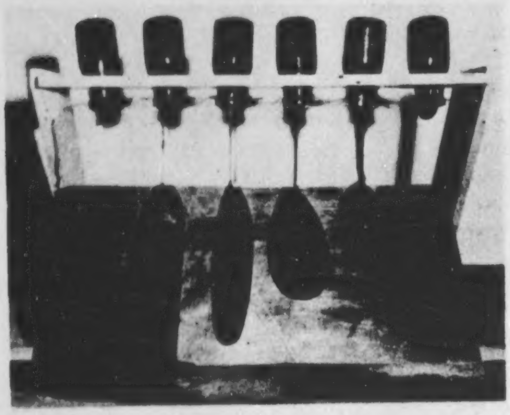
A pour test does not distinguish an asphalt cutback from an emulsion since both will pour. However, emulsions are soluble or dilutable in water whereas cutbacks are not. Moreover, a pour test does not show whether a cutback is an RC, MC, or SC.

A SMEAR test is used to separate an RC from an MC or SC. The smear test is primarily based on the fact that RC is cutback with a very volatile material (naphtha or gasoline). It is possible to tell whether or not a sample is an RC by smearing some of it in a thin layer on a nonabsorbent surface, such as a piece of glazed paper. This will give the volatiles a chance to evaporate. In fact, volatiles will leave an RC within a few minutes. The surface will become so tacky that the specimen, paper and all, will stick to the fingers and be lifted into the air if touched (fig. 5-43). This is not so for MC and SC, which remain fluid and oily for some time; for hours or days in some cases, depending upon the type and grade of the material. A viscous

ASPHALT CEMENT ON LEFT.
ASPHALT CUTBACK ON RIGHT.



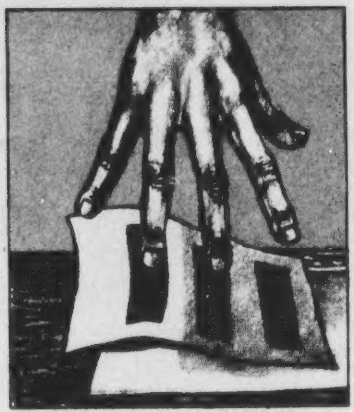
LEFT TO RIGHT: ASPHALT CUTBACKS GRADE 30, 70, 250, 800, AND 3000 THREE SECONDS AFTER TIPPING FULL JARS.



THIRTEEN SECONDS AFTER TIPPING FULL JARS.

143.179

Figure 5-42.—Pour test for asphalt and cutbacks.



LEFT TO RIGHT: RC, MC, AND SC. AFTER 10 SECONDS, ONLY RC IS STICKY.

143.180

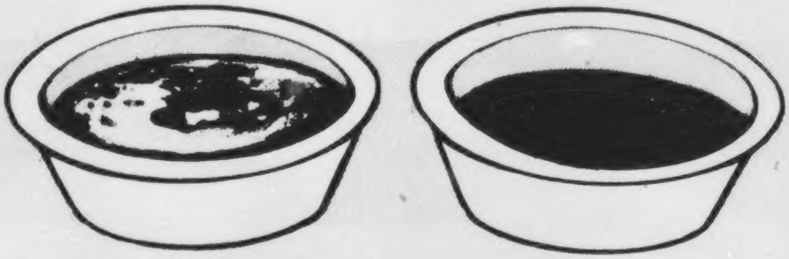
Figure 5-43.—Smear test for asphalt cutbacks.

cutback, like 800 or 3000 grade MC or SC, may become sticky in a few minutes since there is already a small amount of cutterstock in it. In this case, it is best to confirm the identification of each sample by a prolonged smear test.

In a PROLONGED SMEAR TEST, a thin smear is made on nonabsorbent paper and allowed to cure completely. If the viscous cutback is an RC-3000, it will cure completely in about 3 hours. An RC-800 will cure completely in approximately 6 hours. When the spot has cured completely (the cutterstock has almost all evaporated) the smear will be almost pure asphalt cement and will be hard and no longer sticky. If the viscous sample is an MC or SC-800 or 3000, the spot will still be uncured and, therefore, very sticky (even after 24 hours) while the RC smear will have become a hard, glazed spot.

HEAT-ODOR TEST is used to distinguish between medium-curing and slow-curing asphalt cutback by identifying the cutterstock as kerosene, fuel oil, or diesel oil. A sample of the material is heated in a closed container to retain the vapors. (Care should be taken to avoid the use of too much heat.) Medium-curing asphalt cutback will have a strong odor of kerosene.

Slow-curing asphalt cutback will lack the kerosene odor, but a faint odor of motor oil may be present.


LEFT: WATER PLUS TAR OR ASPHALT CUTBACK
RIGHT: WATER PLUS ASPHALT EMULSION

143.182

Figure 5-44.—Water-mixing test for emulsions.

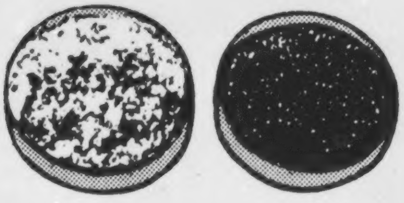
TESTS FOR ASPHALT EMULSIONS

Asphalt emulsions may be identified by their dark brown color, in contrast to the black color of other bituminous materials.

Another test used is the WATER MIXING TEST (fig. 5-44). Because emulsions are made with water, more water may be added to emulsions without disturbing the uniformity of the liquid. None of the other bituminous materials will dissolve in water.

A FLAME TEST also is used in testing asphalt emulsions. A cloth saturated with asphalt emulsion will smolder, but will not burn or burst into flame. Other bituminous materials are combustible.

The STONE-COATING TEST is used to distinguish the nonmixing (rapid-setting) emulsions from the mixing (medium- and slow-setting) emulsions (fig. 5-45). This test will give positive results in the field where large quantities may be used. Damp sand is added to a sample of emulsion to test its mixing capability. A rapid-setting emulsion breaks too quickly to mix with the sand. A medium- or slow-setting emulsion mixes easily with the sand and completely coats all of the particles. Identification of an emulsion merely as a mixing or nonmixing type is sufficient for field conditions. The difference in viscosity is unimportant because there are so few grades. No distinction is necessary between medium- and slow-setting emulsions since both are mixing types used largely for the same purpose.


LEFT: DAMP SAND PLUS RS
RIGHT: DAMP SAND PLUS MS OR SS

143.183

Figure 5-45.—Stone-coating test for emulsions.

TESTS FOR TARS

A POUR TEST is used to identify the 12 viscosity grades of tar. Viscosity grades of road tars are comparable to the viscosity grades of asphalt cutbacks and asphalt cement as shown in table 5-6. RT-1, the most fluid, is similar in viscosity to the 30 grades of the rapid-curing, medium-curing, and slow-curing types of asphalt cutbacks. RT-8 is similar to grade 800 asphalt cutback. RT-12 has the approximate consistency of asphalt cement of 200-300 penetration.

Road tar grades 4, 5, 6, and 7, which are identical in appearance to road tar cutback grades 5 and 6, may be distinguished through a smear test. Like asphalt cutbacks, road tar cutbacks cure rapidly since they are thinned with highly volatile materials, which will evaporate quickly, leaving a sticky substance within a 10-minute period. On the other hand, because the fluid coal oil in road tars evaporates slowly, road tars will remain at about the same consistency at the end of an identical period.

LABORATORY TESTS OF BITUMINOUS MATERIALS

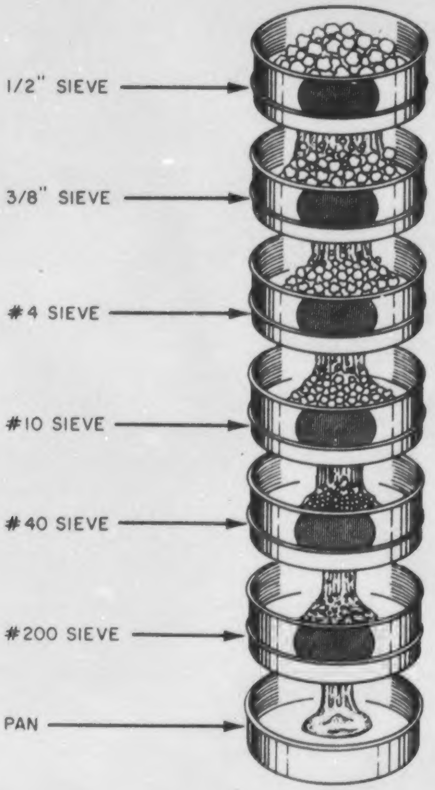
In addition to field tests, various tests are conducted on bituminous materials in the laboratory. These tests usually are made for the purpose of checking compliance with established specifications. However, laboratory tests may also be made to identify the material beyond field identification, to furnish information for mix design, or to establish safe handling procedures.

In regard to specifications, note that bituminous materials are manufactured to meet specifications established by the Federal Government, American Association of State Highway Officials (AASHO), and American Society for Testing Materials (ASTM). These specifications define the extreme limits permitted in the manufacture of the material and assure the user that the material will possess definite characteristics and fulfill the project requirements. Consult with the EA's for the proper specifications required.

AGGREGATES FOR BITUMINOUS PAVEMENTS

A bituminous pavement is one which is made up of a mixture of coarse and fine aggregate bound together by a liquid or semisolid bituminous binder. Bituminous pavements are used as the top portion of the flexible pavement structure to provide a resilient, waterproof, load distribution medium which protects the base course from detrimental effects of water and abrasive action of traffic.

The aggregate used in bituminous pavements may consist of crushed stone, gravel, sand, mineral filler, or similar material. The aggregate transmits the load from the surface to the base course, takes the abrasive wear of the traffic, and provides a nonskid surface. Aggregates normally constitute 90 percent or more by weight of bituminous mixtures, and their properties have a very important effect upon the finished product.



82.181

Figure 5-46.—Sieve analysis.

For bituminous construction, aggregates are classified according to particle size; such as, coarse aggregate, fine aggregate, and mineral filler. The maximum size of aggregate will vary, depending upon construction requirements. Particle sizes are defined by passing a soil mass through several sieves with different sizes of openings, as illustrated in figure 5-46. Particles which pass through a given sieve are said to be PASSING that sieve size; particles which fail to pass through a given sieve are said to be RETAINED ON that sieve. The sieve permits particles smaller than the openings to fall through and retains the larger particles on the sieve. By using sieves with screen openings of different sizes (the largest on the top and the smallest at the bottom), the soil can be separated into particle groups based on size. A weighed sample of aggregate is placed in the top sieve, and the entire set of sieves is vibrated, either by hand or mechanically. The individual weights are calculated as a percentage of the total weight as shown in the following example:

Aggregate passing 1/2-inch sieve and retained on 3/8-inch sieve = 720 grams = 24%
Aggregate passing 3/8-inch sieve and retained on #4 sieve = 600 grams = 20%
Aggregate passing #4 sieve and retained on #10 sieve = 450 grams = 15%
Aggregate passing #10 sieve and retained on #40 sieve = 570 grams = 19%
Aggregate passing #40 sieve and retained on #200 sieve = 420 grams = 14%
Aggregate passing #200 sieve = 240 grams = 8%
3,000 grams = 100%

The above percentages are one way of expressing the gradation of a sample of aggregate. Another way, more commonly used, is to express the gradation in terms of the TOTAL PERCENTAGE that passed each sieve. This is determined by adding the listed percentage that passed each sieve and was retained on the next finer sieve to the percentages listed beside each of the sieves below. For example in the sample, we have just analyzed, 24% passed the 1/2-inch sieve and was retained on the 3/8-inch sieve. The total percentage that passed the 1/2-inch sieve is 24% plus 20% plus 15% plus 19% plus 14% plus 8%, or 100%. The total percentage that passed the 3/8-inch sieve is 20% plus 15% plus 19% plus 14% plus 8%, or 76%. Continuing the calculations as indicated, the results of the test in terms of total percentage passing each sieve are as follows:

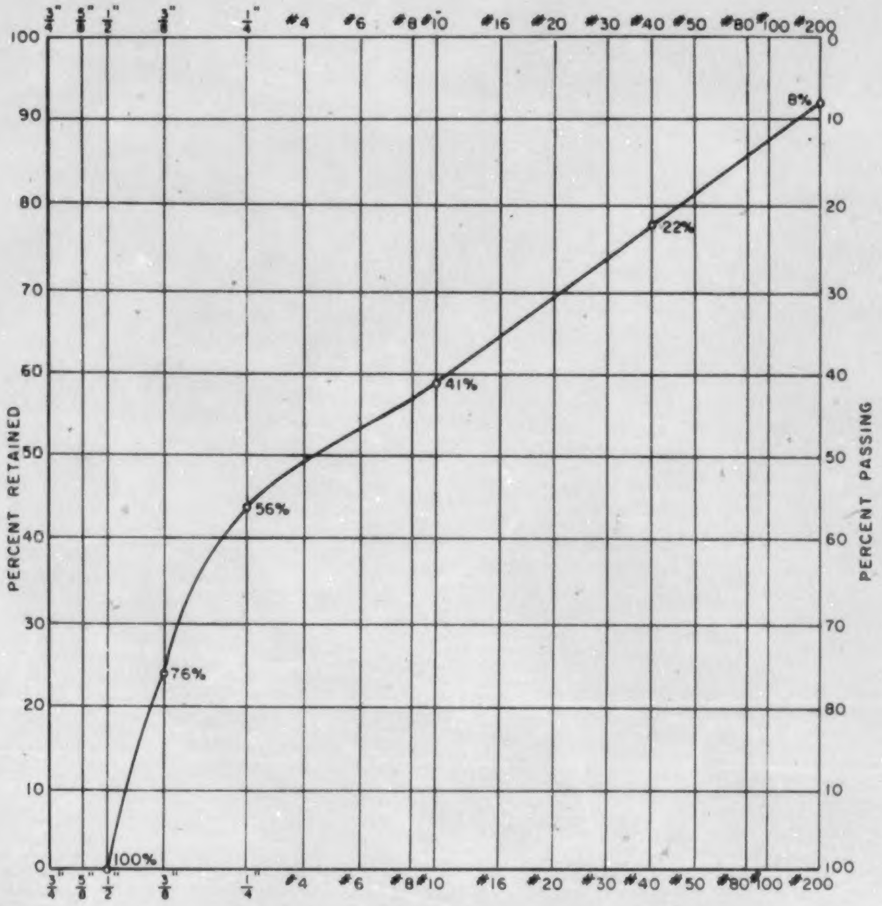
Aggregate passing 1/2-inch sieve = 3,000 grams = 100%
Aggregate passing 3/8-inch sieve = 2,280 grams = 76%
Aggregate passing #4 sieve = 1,680 grams = 56%
Aggregate passing #10 sieve = 1,230 grams = 41%
Aggregate passing #40 sieve = 660 grams = 22%
Aggregate passing #200 sieve = 240 grams = 8%

Figure 5-47 shows the aggregate gradation curve for this particular example, plotted by using the above percentages.

For bituminous aggregate, anything which passes the #4 sieve and is retained on the #200 sieve is considered FINE aggregate; anything retained on the #4 sieve is considered COARSE aggregate. Material which will pass the #200 sieve is some times used in bituminous paving; this material is known as MINERAL FILLER, DUST or FINES. It consists of finely powdered rock, portland cement, hydrated lime, or some other artificially or naturally powdered dust.

All testing sieves larger than 3/16-inch are identified by the actual clear opening in inches, and all testing sieves smaller than 3/16-inch are identified by mesh number. (See Appendix I, Table I-31.)

The bituminous binder used in a bituminous surface serves two functions: one, it binds the aggregate together, thus preventing the



143.184

Figure 5-47.—Sieve sizes.

displacement of the aggregate; and two, it provides a waterproof base and keeps surface water from seeping into and weakening the base course material.

HOT-MIX ASPHALT PAVING

Hot-mix asphalt paving consists of a combination of aggregates uniformly mixed and coated with asphalt cement. To dry the aggregates and obtain sufficient fluidity of the asphalt cement for proper mixing and workability, both the aggregate and asphalt must be heated prior to mixing—hence the term "hot-mix."

Hot-mix asphalt paving mixtures may be produced from a wide range of aggregate combinations, each having its own particular characteristics and suited to specific design and construction uses. Aside from the amount and grade of asphalt used, the principal characteristics of the mix are determined, in the main, by the relative amounts of:

Coarse aggregate (retained on No. 4 sieve)
Fine aggregate (passing No. 4 sieve)
Mineral dust (passing No. 200 sieve)

The aggregate composition may thus vary from a coarse-textured mix having mostly coarse aggregate to a fine-texture mix having mostly fine aggregate.

To assort these variables, the Asphalt Institute classifies hot-mix asphalt paving according to MIX TYPE, based on the relative amounts of coarse aggregate, fine aggregate, and mineral dust. The general limits for each mix type (types "I" through "VIII") appear in chart form in figure 5-48, along with the paving mix designation and the maximum size aggregate NORMALLY used for each of the eight mix types included. The chart is based on the proportions of coarse and fine aggregate in the paving mix used to establish the mix type and on the proportion of mineral dust, the ranges for which are represented by shaded bands. This type of representation is used to denote "flexible" limits as opposed to a "fixed" numerical value.

The area of the classification chart (fig. 5-48) to the left of the shaded band includes the range of mineral dust for each respective mix type, including SURFACE COURSE, BINDER COURSE (sometimes called INTERMEDIATE COURSE), and BASE COURSE mixes. For any given combination of coarse and fine aggregate (i.e., mix type), surface course mixes will

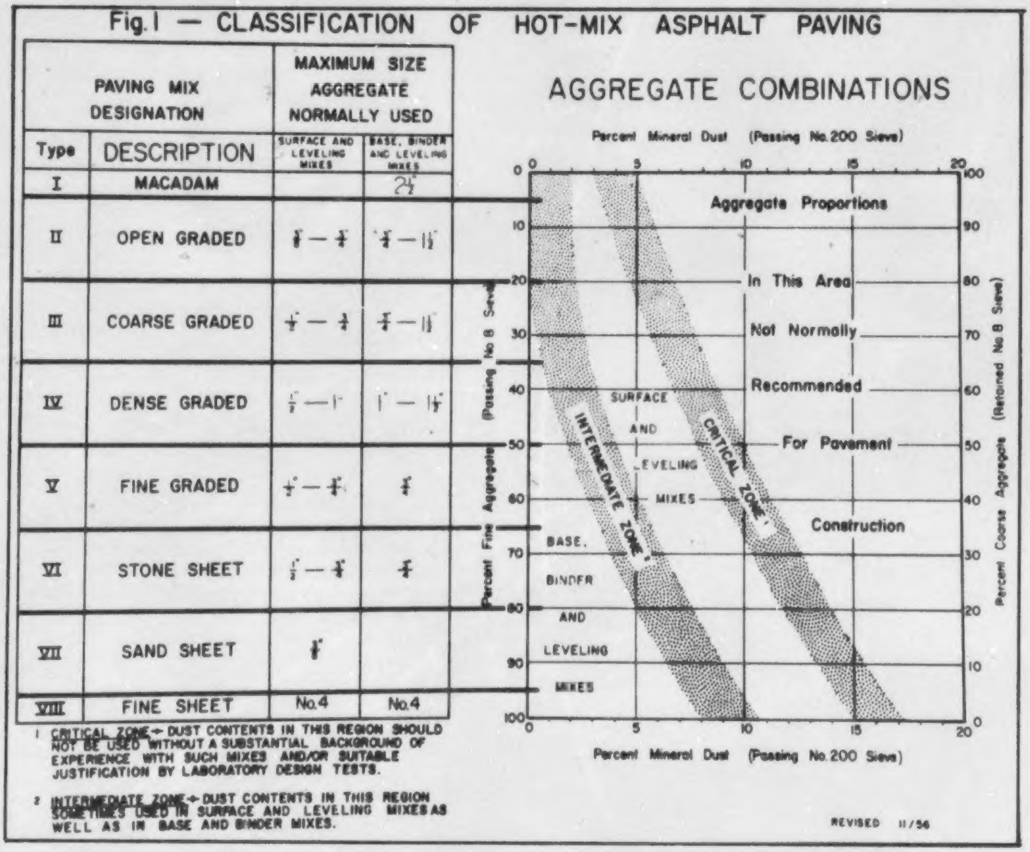


Fig. I — CLASSIFICATION OF HOT-MIX ASPHALT PAVING

PAVING MIX DESIGNATION		MAXIMUM SIZE AGGREGATE NORMALLY USED	
Type	DESCRIPTION	SURFACE AND LEVELING MIXES	BASE, BINDER AND LEVELING MIXES
I	MACADAM		2½"
II	OPEN GRADED	3/8"—3/4"	3/4"—1½"
III	COARSE GRADED	1/2"—3/4"	3/4"—1½"
IV	DENSE GRADED	1/2"—1"	1"—1½"
V	FINE GRADED	1/2"—3/4"	3/4"
VI	STONE SHEET	1/2"—3/4"	3/4"
VII	SAND SHEET	3/8"	
VIII	FINE SHEET	No.4	No.4

[1] CRITICAL ZONE — DUST CONTENTS IN THIS REGION SHOULD NOT BE USED WITHOUT A SUBSTANTIAL BACKGROUND OF EXPERIENCE WITH SUCH MIXES AND/OR SUITABLE JUSTIFICATION BY LABORATORY DESIGN TESTS.

[2] INTERMEDIATE ZONE — DUST CONTENTS IN THIS REGION SOMETIMES USED IN SURFACE AND LEVELING MIXES AS WELL AS IN BASE AND BINDER MIXES.

143.185

Figure 5-48.—Classification of hot-mix asphalt paving.

normally contain more mineral dust than either base or binder mixes; and base mixes will usually contain the least amount of mineral dust. Therefore, for a particular mix type, base and binder course mixes will normally fall on the left side of the chart as indicated, and surface course mixes to the right of these base and binder course mixes. It should be emphasized, however, that there are exceptions.

This method of classification was developed to codify (to arrange) the terminology and designations for hot-mix asphalt paving currently in local practice throughout the construction field. The terms and limits included agree in general with overall practice, but may be at slight variance with the practice of a given local area. Aside from the advantages of standardizing the terminology, the use of this method of paving mix classification permits a logical subdivision of each mix type into a series of mix compostions having specific design uses.

In the proportioning of aggregate and asphalt, it is important to note that the asphalt content may be expressed either as a percentage by weight of total mix or as a percentage by weight of dry aggregate. Each method of specifying asphalt has certain advantages and either method is acceptable, provided it is clearly understood which method is being used. The following example illustrates the two methods: assume that a given mix contains aggregates and asphalt in the proportion of 100 lb of aggregate to 6 lb of asphalt. The asphalt content of such a mix may be expressed as $\frac{6}{100} \times 100 = 6\%$ asphalt BY WEIGHT OF DRY AGGREGATE. This asphalt content may also be expressed as $\frac{6}{100 + 6} \times 100 = 5.66\%$ asphalt BY WEIGHT OF TOTAL MIX.

ASPHALT PLANTS

The Navy needs well-qualified personnel to set up and adjust asphalt plants for production purposes. One way to assure that the personnel are qualified is through special training. The Bureau of Naval Personnel has a class C1 school at Port Hueneme, California and another at Gulfport, Mississippi to indoctrinate EO's in asphalt paving procedures.

As the supervisor, you must see that new personnel coming into your unit receive training which will enable them to properly operate and maintain an asphalt plant. Only after operators are properly trained and adequately supervised can you expect them to be proficient. When only a single new operator is to be trained, assign the person to one of your experienced operators for individual training. When a completely new crew needs training, however, a formal training program should be set up.

The Naval Construction Force uses various makes and models of asphalt plants. There are two main types: continuous flow and batch. The type of asphalt plant used for training personnel at the EO school, NCTC, Port Hueneme, is the Barber-Greene, 65 TPH, continuous-flow asphalt plant shown in figure 5-49. A batch plant is set up for the same purpose at the EO school, NCTC, Gulfport. Both types are described here.

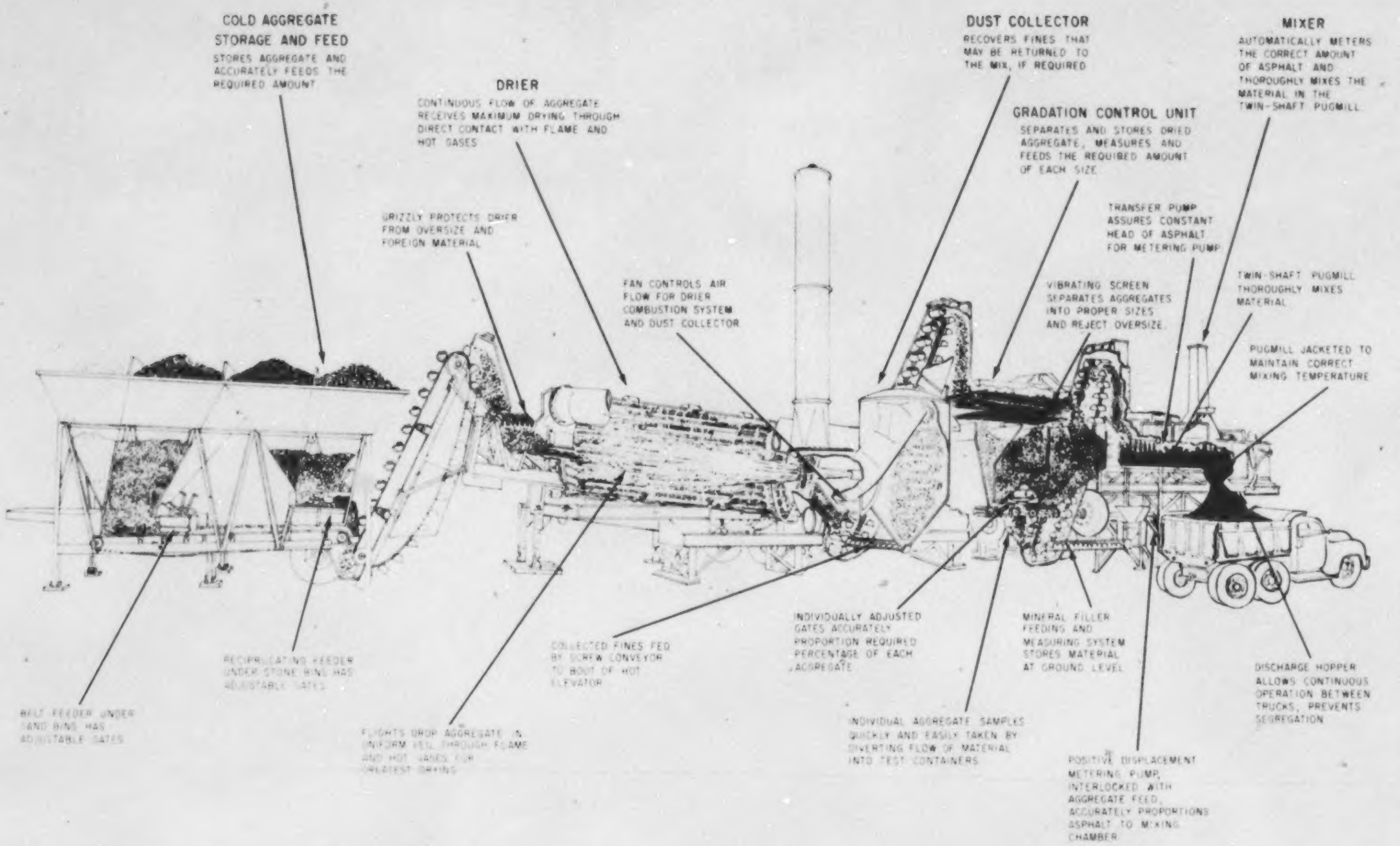
CONTINUOUS-FLOW ASPHALT PLANT

Figure 5-49 illustrates the flow of material through a continuous-flow plant. Although the plant illustrated is for production of the highest-type mixes, the components perform the same functions regardless of the particular setup being used.

As soon as the plant is ready to operate, examine it thoroughly for compliance with specifications and requirements set forth by the plans or the project officer. Remember, the primary source of complete and authentic information on the operation and maintenance of any particular type of asphalt plant is the manufacturer's operating and maintenance manuals.

Cold Feed

The cold aggregate feed is one of the critical control points in the production of asphalt mixes. While some of the problems occur in the dryer, on the plant screens or bins, or in the


COLD AGGREGATE STORAGE AND FEED
STORES AGGREGATE AND ACCURATELY FEEDS THE REQUIRED AMOUNT
DRIER
CONTINUOUS FLOW OF AGGREGATE RECEIVES MAXIMUM DRYING THROUGH DIRECT CONTACT WITH FLAME AND HOT GASES
GRIZZLY PROTECTS DRIER FROM OVERSIZE AND FOREIGN MATERIAL
FAN CONTROLS AIR FLOW FOR DRIER COMBUSTION SYSTEM AND DUST COLLECTOR
DUST COLLECTOR
RECOVERS FINES THAT MAY BE RETURNED TO THE MIX, IF REQUIRED
GRADATION CONTROL UNIT
SEPARATES AND STORES DRIED AGGREGATE, MEASURES AND FEEDS THE REQUIRED AMOUNT OF EACH SIZE
MIXER
AUTOMATICALLY METERS THE CORRECT AMOUNT OF ASPHALT AND THOROUGHLY MIXES THE MATERIAL IN THE TWIN-SHAFT PUGMILL
TRANSFER PUMP ASSURES CONSTANT HEAD OF ASPHALT FOR METERING PUMP
VIBRATING SCREEN SEPARATES AGGREGATES INTO PROPER SIZES AND REJECT OVERSIZE.
TWIN-SHAFT PUGMILL THOROUGHLY MIXES MATERIAL
PUGMILL JACKETED TO MAINTAIN CORRECT MIXING TEMPERATURE
BELT FEEDER UNDER SAND BINS HAS ADJUSTABLE GATES
RECIPROCATING FEEDER UNDER STONE BINS HAS ADJUSTABLE GATES
FLIGHTS DROP AGGREGATE IN UNIFORM VEIL THROUGH FLAME AND HOT GASES FOR GREATEST DRYING
COLLECTED FINES FED BY SCREW CONVEYOR TO BOOT OF HOT ELEVATOR
INDIVIDUALLY ADJUSTED GATES ACCURATELY PROPORTION REQUIRED PERCENTAGE OF EACH AGGREGATE
INDIVIDUAL AGGREGATE SAMPLES QUICKLY AND EASILY TAKEN BY DIVERTING FLOW OF MATERIAL INTO TEST CONTAINERS
MINERAL FILLER FEEDING AND MEASURING SYSTEM STORES MATERIAL AT GROUND LEVEL
POSITIVE DISPLACEMENT METERING PUMP, INTERLOCKED WITH AGGREGATE FEED, ACCURATELY PROPORTIONS ASPHALT TO MIXING CHAMBER
DISCHARGE HOPPER ALLOWS CONTINUOUS OPERATION BETWEEN TRUCKS, PREVENTS SEGREGATION

143.65

Figure 5-49.—Continuous-flow asphalt plant.

pugmill, most of the causes usually can be traced back to the cold feed.

The cold aggregate feeder is a major component of the hot-mix asphalt plant. The feeder may be charged by clamshell or front-end loader. Aggregate feeder units should have controls that can be set and secured to produce a uniform flow of aggregate to the cold elevator.

For a uniform OUTPUT from the asphalt plant, INPUT must be accurately measured. The importance of feeding the exact amounts of each size aggregate into the dryer at the correct rate of flow cannot be overemphasized.

The following conditions will best assure a uniform flow of the aggregate sizes:

1. Correct sizes of aggregate in the stockpiles.
2. No intermixing of stockpiles.
3. Accurately calibrated, set and secured feeder gates.
4. Gates kept free of obstruction.
5. No excessive arching in the fine aggregates. This can be minimized by using rectangular (rather than square) openings above the feeders and/or placing vibrators on the outside of the fine aggregate bins. Vibrators should be wired to cut off automatically when the feeder stops. This eliminates excessive packing in the bin.

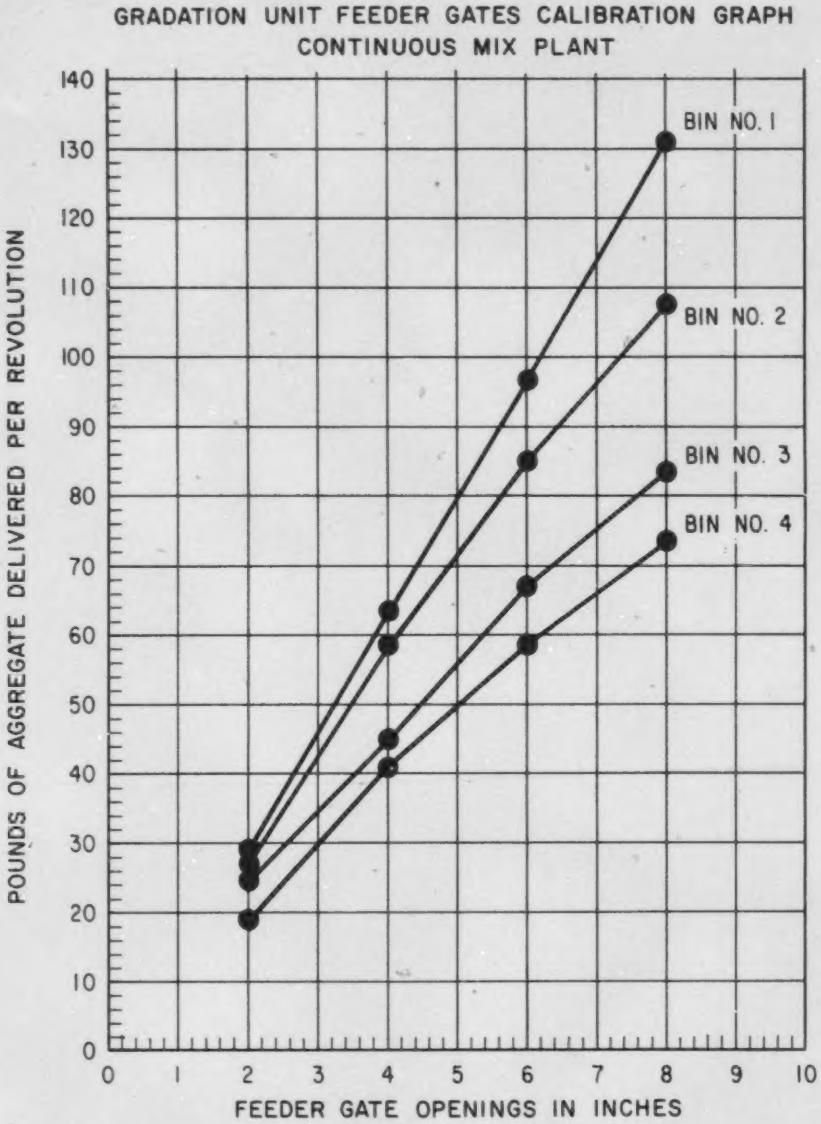
The following conditions underscore the need for proper cold feeding:

1. Wide variations in moisture or in quantity of a specific aggregate at the cold feed may cause a considerable change in the temperature of the aggregate leaving the dryer.
2. A sudden increase in the cold feed can overload the screens, creating a carryover of the fine aggregate into the coarse aggregate bins.
3. Erratic feeding may cause some bins to overfill while starving others, leading to such problems as:
    a. Layers of variable grading in the hot bins gradation unit storage, especially in the fine bin, resulting in alternating rich and lean batches.
    b. Overloaded dust collection system.
    c. Reduced dryer draft.

The cold aggregate feeder gates should be calibrated. Most manufacturers furnish approximate calibrations for gate openings of their equipment. When these are available, they are helpful in making the initial gate setting. But the only accurate way to set gates is by making a calibration chart for each gate, using the aggregate to be employed in the mix. The gate opening (in inches or square inches) is plotted on the chart as the horizontal coordinate, and the pounds of material per revolution of the feeding mechanism (or pounds per minute) as the vertical coordinate. To prepare the calibration chart, the gate is set, usually at 25 percent or less of the total opening, and the feeder is started. When the feeder is running normally, material is measured for a known time interval, or number of revolutions, into a tare container and weighed. This gives one point on the calibration chart. The operation is repeated for three or more gate openings and the points connected on the chart (fig. 5-50). After the gates have been calibrated and locked, minor adjustments may be necessary to assure uniform production.

When the gates discharge on to the belt conveyor, their output may be checked by closing all gates except one, which is set at one of the calibration points. If the gates cannot be closed completely, it may be necessary to stop the feeder, or disconnect it if it is mechanically driven. The plant is started and brought to normal operating speed. Then the plant is stopped and the material from a measured section of the belt is removed and weighed, using care to remove all fines. The weight of the material, divided by the length (in feet) of the belt section, multiplied by the belt speed (in feet per minute), will give the amount of material delivered per minute from the gate opening. The material from other gate openings is determined in the same manner and the gate calibration chart plotted as described above.

When variable speed drives are used to control belt feeders, calibration is simplified. The gate opening can be estimated and the speed of the belt can be increased or decreased to deliver the required percentage and tonnage of aggregate.



143.186

Fibure 5-50.—Calibration chart, gradation feeder gates.

In calculating the output of a gate for a given opening, deduct the weight of surface moisture on the aggregate being weighed. This is very important when calibrating gates through which fine aggregates are flowing.

For uniform flow, gates that feed coarse aggregate should not be set at less height than 2 1/2 to 3 times the largest aggregate size. For example, if a gate is feeding aggregate of 1-inch maximum size, the gate should not be set at less than 2 1/2 or 3 inches. Sometimes it may be necessary to restrict the opening width to provide the necessary opening height.

Before setting cold feed gates, the production volume of the plant in normal operation must be determined. This can be estimated from the plant size (dryer, screening and mixing capacities) and mixing cycle time. Then, using the gate calibration charts, each gate is set to deliver its share of the desired volume of aggregate.

Grading of the individual cold aggregate is determined by sieve analysis. The percentage of each size of aggregate to be used is calculated by trial and error.

The proportions required on the basis of these percentages will determine the gate settings. These settings should be checked by the same method used in calibrating the gate originally.

The setting should be considered tentative because the cold aggregate may vary in grading and moisture with weather and other conditions which will affect its bulking and flow.

The hot bins should be watched carefully and the cold aggregate feeders regulated to see that they do not run out of material or overflow.

Dryer

The dryer (fig. 5-49) is a revolving cylinder, usually ranging from 3 to 10 feet in diameter and from 15 to 40 feet in length, in which aggregate is dried and heated by an oil or gas burner. The cylinder is equipped with longitudinal cups or channels, called lifting flights, which lift the aggregate and drop it in veils through the burner flame and hot gases. The slope of the cylinder, its speed, diameter, length and the arrangement and number of flights control the length of time required for the aggregate to pass through the dryer.

The dryer performs two functions: (1) it vaporizes and removes the moisture, and (2) it heats the aggregate to mixing temperature.

There are tow basic types of oil burners used in dryers. One uses steam for atomizing the fuel oil, and the other uses low pressure air. There are also low and high pressure gas burners, combination oil and gas burners, and liquid petroleum gas (LPG) burners.

Most dryers are designed for average aggregate moisture content. Very wet aggregate will reduce the dryer capacity and require corrective measures, two of which are: the amount of heat is increased by burning more fuel while the flow of aggregate remains constant, or the aggregate flow is reduced. There is a limit to the increase in heat that is possible without increasing exhaust draft capacity. Beyond that limit the draft must be increased or the rate of aggregate flow must be reduced.

Aggregates with highly absorptive characteristics may require longer drying periods. The supervisor can accomplish this by rearranging the dryer flights or changing the incline of the dryer. In very humid areas, or when aggregates are exceptionally wet, the specification may require, or the supervisor may elect, to operate two dryers in tandem.

Most problems in dryer operation are caused by crowding more material through the dryer than it can properly handle. However, there are other factors which will affect efficient operation. Several of these involve the burner. If the dryer is equipped with an oil burner, it is important that the proper grade of fuel oil be used. It is also important that the fuel oil NOT be contaminated. The burner must be adjusted so that the air (or steam) furnished by the blower properly atomizes the oil. In addition, the velocity of the draft air, which combines with the atomized fuel oil for combustion, must be in balance with the blower air and the amount of fuel oil being fed into the burner. This adjustment is largely governed by the draft, supplied by the suction of the exhaust fan and the secondary air opening around the burner.

If the blower air, draft air, and amount of fuel oil are not in balanced adjustment, it can cause incomplete combustion of the fuel, leaving on the aggregate particles an oily coating harmful to the finished mixture. Black smoke from the exhaust stack indicates that the oil is not being completely burned. This may be corrected by decreasing the amount of fuel oil or by increasing the blower or the draft air. If a bag house or wet wash system is in operation with the dust collector, it may not be possible to observe black smoke from the exhaust stack.

Lack of balance between blower air and draft air velocities also can create back pressure within the dryer drum, causing "puff back" at the burner end. Puff back indicates that the draft is not sufficient to accommodate the air pressure being introduced by the burner blower. The solution is to increase the draft or to reduce the pressure of the blower air.

Dryer burners using natural gas or liquid petroleum gas rarely develop combustion problems. However, an imbalance between gas pressure, combustion air, and draft still can occur. Make sure the gas burner you use is the correct type for the pressure of the gas available.

Overheating of the aggregate can damage the asphalt during mixing. Unheated aggregate is difficult to coat with asphalt and the resulting mix is difficult to place. Therefore, a reliable and accurate temperature-measuring device (a pyrometer) should be installed in the dryer discharge, in full view of your burner operator.

The pyrometer should be cleaned periodically. Dust accumulating on it may cause a time lag in temperature measurement. It should also be checked frequently for accuracy. A simple way to do this is to put its sensing element, together with an accurate thermometer, in an oil or asphalt bath, then heat the oil or asphalt and compare readings from the pyrometer and thermometer. These readings should be taken at temperatures below, through, and above the expected operating temperature range.

Dust Collector

Most dust collectors (fig. 5-49) are centrifugal (cyclone) units, either horizontal or vertical with single or multiple shells. Dust particles in the current of draft air from the dryer enter the top of the dust collector, drawn by the fan(s) that pulls the flame and the hot gases through the dryer. In the collector, the dust laden air is forced into a whirling motion.

The heavier dust particles in the exhaust gas stream are separated by centrifugal force against the collector shell and are carried to the lower outlet. The finer dust may remain in suspension and be carried out the exhaust stack with the air, depending on the collector efficiency.

When required by specifications, a bag house or wet wash system is added to the dust collecting system. There are several types of wet systems, but they usually consist of a short tower, with or without baffles, or multiple horizontal tubes with spirals. The washer swirls the high velocity exhaust from the fan of the dust collector through fog and fine spray to both wash the gas and throw the dampened fines to the sides by centrifugal force. The material washes down the sides and discharges, with the water, out the bottom of the washer. Use of a wet wash system usually will increase fan requirements by 10 to 25 percent because of pressure loss in the tower.

If the material removed from the dust collector can be recombined satisfactorily with the aggregates in the mix, some or all of it may be returned to the plant. The amount returned will depend upon the combined grading of finished mix. If the collected dust is unsatisfactory or is prohibited by the mix specifications, it is removed from the bottom of the collector and wasted.

Hot Screens

Aggregate from the dryer is delivered hot passing on or through the screens, which are mounted over the gradation unit bins. The function of the hot screens is to accurately separate the aggregate into the specified sizes. To perform this function properly, the effective screening area must be large enough to handle the maximum feed. Therefore, the capacity of the screens should be checked against the capacity of the dryer.

Screen capacity is dependent upon the type of screen, screenability of the aggregate, and specification requirements. As a result, the tons per hour processed per square foot of screen area will vary. Table 5-8 may be used as a general guide in determining screen capacity.

The above table may be used for dried aggregate where blending (mixing of), moisture buildup, or other such screening problems will not be encountered. In this table, it is assumed that approximately 25 percent of the screen load is retained. For example, for a 100-ton per hour capacity the approximate total load on the screen is 133 tons per hour.

The condition and cleanliness of the screens will, to a large extent, control their efficiency. If

Table 5-8.—Vibrating Screen Capacity

Clear Opening Screen Size	TPH Per Square Foot	TPH For Screen Sizes Listed Below		
		3′ x 8′	4′ x 10′	4′ x 14′
No. 8	1 1/4	30	50	70
1/8 inch	1 1/2	35	60	85
3/16 inch	2	50	80	110
1/4 inch	2 1/2	60	100	140
3/8 inch	3 1/4	80	130	180
1/2 inch	3 3/4	90	150	210
5/8 inch	4 1/4	100	170	230
3/4 inch	4 3/4	115	190	265
7/8 inch	5 1/4	125	210	295
1 inch	5 3/4	140	230	320

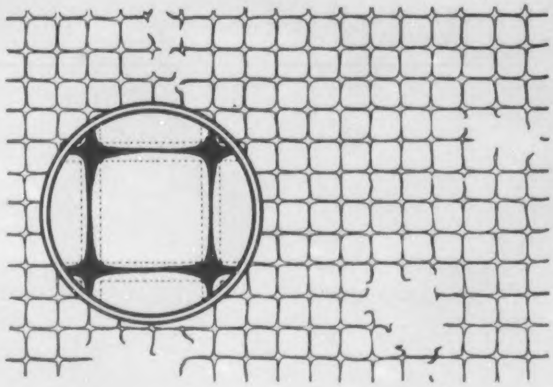
Note: The values in this table are neither the maximum nor minimum that may be expected. The capacity will be affected by many factors, including aggregate moisture content, gradation of the material, screen load versus amount passing, and size of screen wire.

the effective screening area is reduced by plugged screen openings, or if more material is fed to the screens than they can handle, the usual result is "carryover" (discussed later).

Excessive wear of the screen wire causes enlarged openings and holes (fig. 5-51), resulting in oversized material in the bin. Usually, a small amount of oversized material in the bin does no harm, provided the amount does not fluctuate excessively or exceed specification requirements.

In some instances, screening effectiveness can be improved by using screens having small wire diameter or different shaped openings. Uniform distribution of aggregate over the full width of the screens, and the use of a ball-deck (especially on the sand screen), to decrease choking or binding also will increase efficiency.

When screen openings are plugged, or when too much material is fed to the screens, many of the particles that should pass through ride over them and are dropped into a bin that is meant to contain a larger size. Carryover, then, is the depositing in a bin of material that is finer than that specified.



143.187

Figure 5-51.—Screen wear.

Varying carryover causes a lack of uniformity in the aggregate gradation and in the mixture. Excessive carryover adds to the amount of fine aggregate in the total mix, thus increasing the surface area to be coated with asphalt. Excessive carryover, or its fluctuations, will be apparent from the sieve analyses made from the contents of the individual hot bins. Corrective measures include the cleaning of screens, regulating the quantity of material coming from the cold feed, or a combination of both. This carryover condition will be experienced more often where fine screening area (No. 1 bin) is limited. Some carryover is permitted in normal screening, however, and the permissible amount in each bin usually is specified.

Daily visual inspection of the screens for cleanliness is recommended, preferably before the start of the day's operations. When conditions warrant, the screens should be cleaned.

Hot Bins

Plant bins temporarily store the heated screened aggregates in the various size fractions required. They should be large enough to prevent running out of material when the mixer is operating at full capacity. And their partitions should be tight, free from holes, and of sufficient height to prevent intermingling of aggregates.

Each hot bin should be equipped with an overflow pipe to prevent aggregate from backing up into other bins. Overflow pipes also prevent overfilling to the point where the vibrating screen will ride on the aggregate, resulting in heavy carryover and possible damage to the screens. The overflow vents should be checked frequently to make sure they are free flowing. When intermingling occurs, the specified gradation is destroyed, as will be indicated by the routine sieve analysis of the hot bin materials.

Sometimes the finer fraction of the aggregate hangs up in the bin corners. When this buildup of material releases, it results in an excess of fines in the mix. The rush of fine material normally occurs when aggregate in the bin reduces to a low level. The condition can be alleviated by having fillet plates welded in the bin corners to eliminate the 90-degree angles.

Other potential obstacles to a good mix include shortages of material in one bin or an excess in another, worn gates at the bottom of the bins that allow leaking of aggregate, and sweating of the bin walls.

Bin shortages or excesses must be corrected by adjusting the cold feed.

Sweating occurs when moisture vapor in the aggregate and in the air condenses on the bin walls. This usually happens only at the beginning of the day's operation or when coarse aggregate is not thoroughly dried. Sweating may accumulate dust which, when released suddenly will add unwanted fines to the mix.

Bin Sampling

Most modern hot-mix asphalt plants are equipped with devices for sampling hot aggregate from the bins. These vary in design but usually serve to divert the flow of aggregate from the feeders, or gates, under the bins into sample containers. On continuous plants, the best place to obtain a sample is from the feeder gates as the material is deposited on to the elevator leading to the pugmill. It is essential that sampling facilities be constructed and located so that the samples obtained will be representative of the material in the bins.

In the flow of material over the screens, finer particles fall to the near side of the bins and coarser particles fall to the far side (fig. 5-52). When material is drawn from a bin by opening a gate at the bottom, the stream

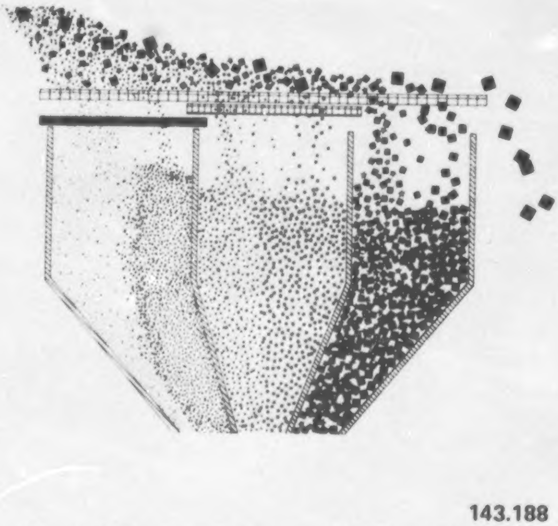


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Figure 5-52.—Segregation of material in the hot bins.

consists predominantly of fine material at one edge and coarse material at the other. This condition is critical in the No. 1, or fine, bin, since the asphalt demand is influenced heavily by the material from this bin. Therefore, the relative position of the sampling device in the stream determines whether the sample will be composed of the fine portion, the coarse portion, or will be an accurate representation of the material in the bin.

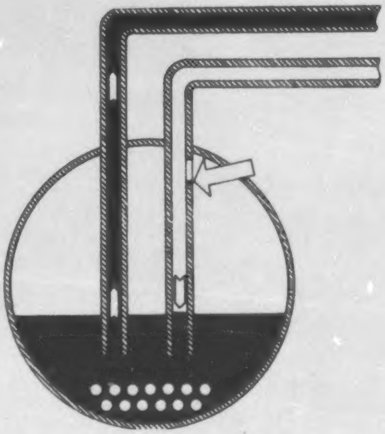
Stratification of sizes in the fine bin may be caused by variation of grading in the stockpiles or by erratic feeding of the cold aggregate. When this form of segregation exists, representative samples cannot be obtained even when the sampling device is used correctly.

Morning and evening measurements of asphalt in storage tanks, with deliveries added, provide checks on the quantity used during the day's run. Occasionally more frequent checks may be desired. These measurements are compared with the quantities as determined from the records kept on how well the asphalt input was controlled. Any large differences in the starting figures and ending figures will call for an investigation of the asphalt storage and feed system to correct any irregularities.

When correcting from volume to weight in measuring asphalt, the asphalt temperature must be taken at the time of gaging or use, and the volume corrected to standard temperature.

Asphalt Heating And Circulation

Provisions should be made for circulation of asphalt through the feeding and storage system. All storage tanks, transfer lines, and pumps should have heating coils and/or jackets to maintain the asphalt at the required temperature. Return lines discharging into the storage tanks should be submerged below the asphalt level in the tank at all times to prevent oxidation of the asphalt. To break the vacuum in the lines when the pump is reversed, two or three vertical slots should be cut in the return line within the tank, but above the high level mark of the stored asphalt (fig. 5-53).



143.189

Figure 5-53.—Asphalt return line. (Large arrow points to vertical slot.)

An armored thermometer or pyrometer with a recorder should be placed in the asphalt feed line at a location near the discharge valve at the mixer unit to assure control of the asphalt temperature. The asphalt storage tank also should be equipped with a recording thermometer having a minimum time range of 24 hours.

An approved valve or spigot should be installed in the tank or in the circulating system to provide a means of sampling asphalt. Sufficient material must be drawn and wasted before the sample is taken to assure that material truly representative of the storage supply is obtained.

If the asphalt temperature is maintained by circulating heating oil, the hot-oil level in the reservoir of the heating unit should be inspected frequently. If the level falls, check for leakage of the hot oil into the stored asphalt.

Temperature of Mixture

Both asphalt and aggregate must be heated before they are combined in the pugmill—the asphalt to make it fluid enough to coat the aggregate particles, and the aggregate to make it dry and hot enough to keep the asphalt fluid while coating the particles.

Asphalt is a thermoplastic material that decreases in viscosity with increasing temperature. The relationship between temperature and viscosity, however, may not be the same for different sources or types and grades of asphaltic material.

The temperature of the aggregate controls the temperature of the mixture and a mixing temperature normally is specified. But, because of these viscosity variations and other factors, the specifying of temperature ALONE is inadequate for the most effective use of the asphalt. Aggregate characteristics and gradation must be considered–such as whether the particles are porous or dense and whether the aggregate is dense-graded or open-graded. Other considerations are the temperature required to dry the aggregate sufficiently to obtain a satisfactory mix and whether this temperature is enough to maintain the viscosity of the asphalt required for effective mixing.

The Asphalt Institute, therefore, recommends that the temperature-viscosity relationship for the asphalt be taken into consideration to arrive at a mix temperature (the mix temperature is determined immediately after the mix is dropped from the pugmill) which will provide the proper asphalt viscosity in open-graded mixer.

The battalion engineering office should furnish you with data on the temperature-viscosity relationship of each asphalt required for the project, including the range of the temperature and viscosity within which the asphalt may be used. On the basis of these data, you can specify the temperature at which the material is to be used.

In absence of suitable temperature-viscosity data, the chart in figure 5-54 will provide a guide for use in determining mixing temperatures.

Mineral Filler Control

When mineral filler is added to the mix, the amount used should be checked frequently. If it is delivered in sacks, the following method may be used:

1. After a truck has been loaded, make certain the filler hopper is full for the series of loads to be checked.

2. Count the sacks of filler added to the hopper when loading the test trucks. Remember that the filler hopper must be full at the end of the test.

3. The number of sacks added during the test, multiplied by the weight of filler per sack, equals the weight of filler in the test loads.

4. Weight of filler, divided by weight of dry aggregate and filler, times 100, equals percent filler.

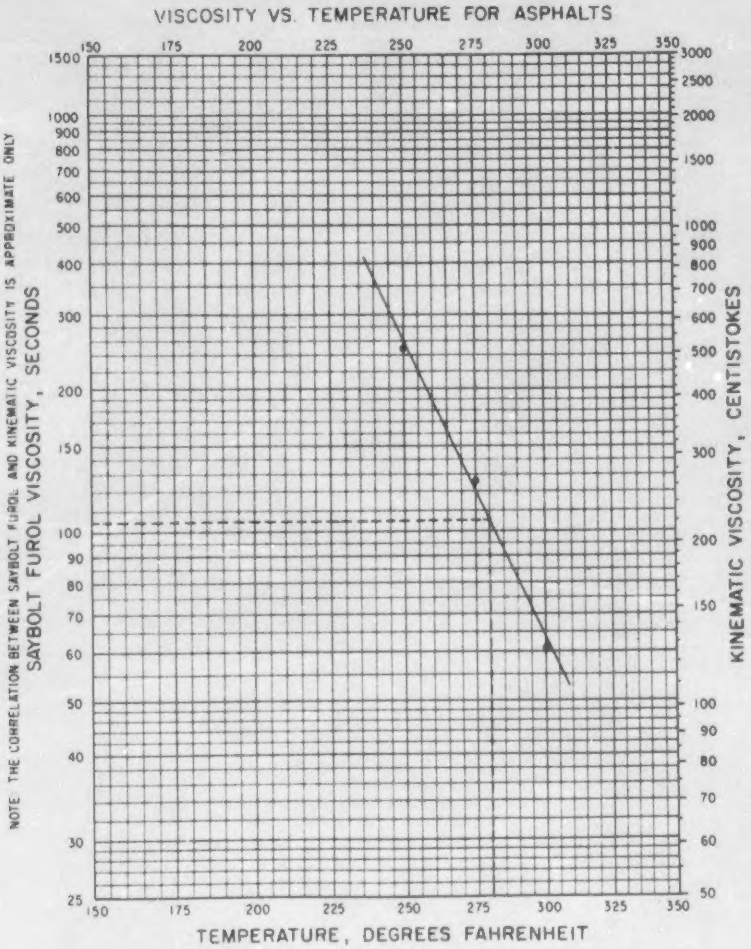
EXAMPLE: The test is run during the production of four truckloads of paving mix. The net weights are:

12,150 lb
12,079 lb
12,240 lb
12,208 lb
Total 48,677 lb of mixture produced during filler check.

While these trucks were being loaded, 23 sacks of mineral filler were added to the mineral filler hopper to keep it level full. Each sack contained 80 pounds of filler.

80 x 23 = 1,840 lb mineral filler.
48,677 x .055 = 2,677 lb asphalt by weight of total mix.
48,677 - 2,677 = 46,000 lb aggregate and filler.
100 (1,840 ÷ 46,000) = 4.0% mineral filler (based on dry mix).

This mineral filler check should be run over a loading period of several trucks. This will



143.190

Figure 5-54.—Viscosity vs. temperature chart for asphalt.

minimize any error in estimating the weight of a partially used sack of filler, and in personal judgment as to when the filler hopper is level full at the beginning and end of a check.

The flow of filler should be checked visually at frequent intervals. The gate opening is small and foreign matter, especially pieces of the paper sacks in which the filler is shipped, will obstruct the flow and sharply reduce the volume of filler added to the mixture. Also, moisture can cause caking, which will obstruct the flow. See that measures are taken to keep the filler dry.

These same check tests may be performed with mineral filler from bulk storage when the amount of filler can be accurately determined. When mineral filler is supplied and stored in bulk, it is generally impractical to measure the amount in storage. Calibration of the feeding and weighing mechanisms must be checked closely and frequently.

Asphalt Distribution

Continuous mix asphalt plants are equipped with positive displacement asphalt pumps. One type is regulated by changing the drive sprockets or gears, mechanically interlocked with the aggregate feeders (fig. 5-55). The other is controlled by a calibrated remote control handwheel on the mixer operator's platform. When using the former type it is necessary to use the manufacturer's tables as a basis for determining the proper pump and sprocket combinations to fix the amount of asphalt discharge. It should be possible to control the feeder gates and asphalt pump so that no change in setting can be made without the knowledge of the petty officer in charge.

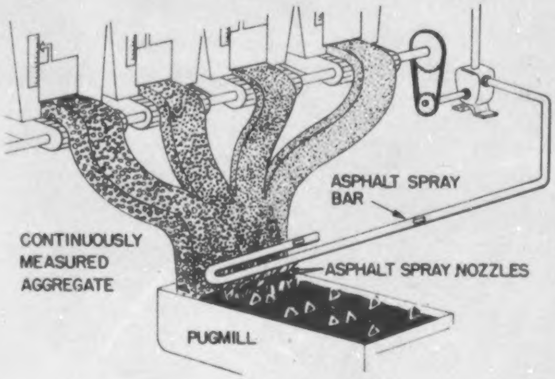
To maintain constant asphalt proportioning, the temperature of the asphalt going through the pump must be known at all times. You should take frequent readings of the thermometer installed in the circulating line just ahead of the pump so that you can make any necessary adjustments to compensate for volume changes in the ashpalt with temperature changes. Pump adjustments are not necessary, however, for minor temperature variations.

Pugmill Mixer

Generally, the function of a continuous mix pugmill is the same as for the batch mix plant. However, the mixing principle is different. In a batch mixer the materials are confined in the mixing chamber. In a continuous mixer, the materials are propelled toward the discharge. The mixing pressure varies with the height or weight of material in the pugmill, which can be controlled by adjusting the dam gate at the discharge. The height of material in the continuous mixer should not be above the paddle tips, except for the last set of paddles.

To improve mixing efficiency, it may be desirable to make the following adjustments:

1. Raise the dam on the discharge end of the mixer to hold the material in the mixing unit for a longer period of time at a depth that will further intensify the mixing action.



143.191

Figure 5-55.—Spray bar operation with asphalt distribution mechanically interlocked with aggregate feeders.

2. Adjust or reverse the pitch of the paddles to retard movement of the material through the pugmill and increase the degree of mixing action within the unit.

Non-uniform mixing may occur if the mixer is overfilled. At maximum operating efficiency, the paddle tips should be barely visible in the material at the top of their periphery during mixing. Material above this level tends to float above the paddles and is not mixed (fig. 5-56). On the other hand, an insufficient batch will not be mixed properly either, because there is not enough material for the paddles to carry around in their paths (fig. 5-57). Both conditions can be minimized if the manufacturer's pugmill batch rating recommendation is followed. The batch rating is based on a percentage of the capacity of the pugmill's "live zone," as defined by the Bituminous Equipment Manufacturers Bureau of Construction Industry Manufacturers Association. The live zone (fig. 5-58) is the net volume in cubic feet below a line extending across the top arc of the inside body shell radius, with shafts, liners, paddles, and tips deducted.

There will not be a uniform mixture if the fines and asphalt in the mixture are not uniformly distributed. Distribution of the fines will be affected by the sequence of bin withdrawal. Malfunctioning of the asphalt

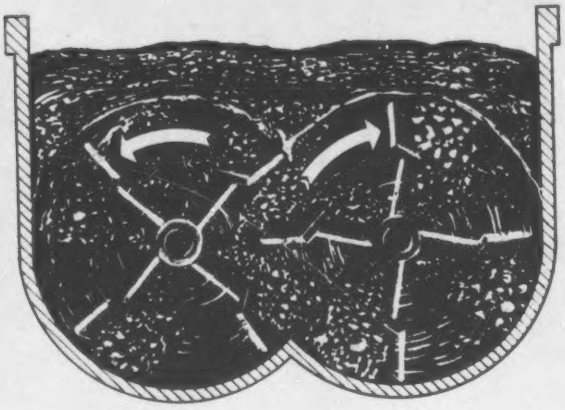


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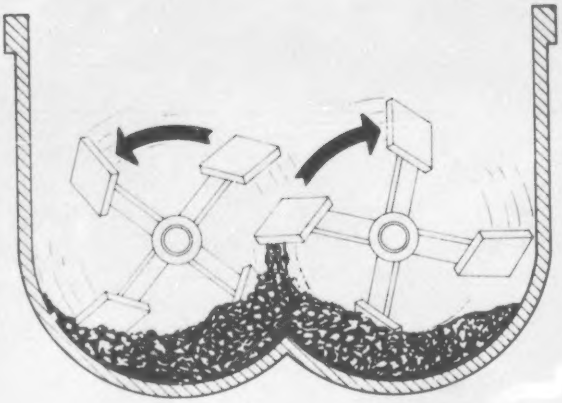
Figure 5-56.—Overfilled pugmill.



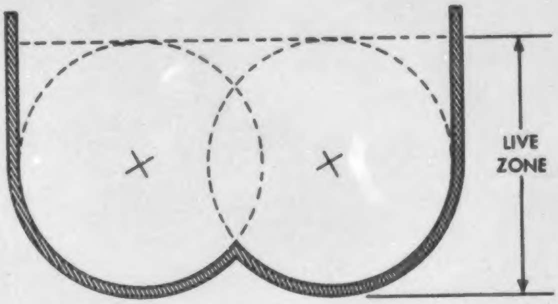
143.193

Figure 5-57.—Underfilled pugmill.

distribution system will result in a non-uniform distribution of the asphalt. Visual inspection and tests of the finished product will indicate either condition. An increase in the dry-mixing time may be necessary to obtain uniform distribution of all sizes of aggregate throughout the mixer.

Mixing Time

Total mixing time begins when all the combined mineral aggregates are in the mixer and ends with the opening of the mixer discharge gate. Dry mixing time, when specified, begins when all the combined mineral aggregates are in the mixer and ends with the introduction of the asphalt. Wet mixing time begins with the start of the asphalt application and ends with the opening of the mixer discharge gate.



143.194

Figure 5-58.—Pugmill "live zone."

The asphalt film on aggregate is hardened by exposure to air and heat. The mixing time, then, should be the shortest time required to obtain a uniform distribution of aggregate sizes and a uniform coating of asphalt on all aggregate particles. Speed of the mixer shafts and the arrangement and pitch of the paddles are factors governing the efficiency of the mixing.

To aid further in the operation of a continuous mix plant, several automatic controls can be added or extended to include:

1. Automatic burner controls.
2. Automatic mix discharge.
3. Automatic mixer and gradation cutoffs in case of hot bin shortage or improper feed.
4. Electric interlocks that shut down the complete plant in case of a failure anywhere in the plant's electric system.

The operator's manual for the particular plant being used gives details on the set up and adjustments of the automatic equipment included with the plant.

Some tables related to asphalt are presented in Appendix I of this manual. Additional tables can be found in asphalt handbooks and in manufacturers' technical manuals for specific equipment or material.

BATCH ASPHALT PLANT

The batch asphalt plant shown in figure 5-59 is the type of plant set up at the EO School, Gulfport. Notice that the cold aggregate storage and feed, dryer, and dust collector are the same as those in the continuous-flow asphalt plant. A distinguishing feature of the batch plant is the batching unit shown in figure 5-60. Here the dried aggregate is screened into different sizes and stored by size in separate bins.

Aggregate Weigh-Hopper

For automatic operation, the weigh-hopper compartments are preset to hold the correct weight of each aggregate. Gates over the weigh-hopper compartments open together, enabling all compartments to fill and form solid columns of aggregate extending past the gates up into the storage bins. The gates then close together, striking off the aggregate in each compartment. The weigh-hopper compartments discharge into the pugmill at the same time.

Asphalt Weigh-Bucket

As the aggregates enter the pugmill, the asphalt weigh-bucket automatically delivers the required number of pounds of asphalt per batch. A scale mounted on the bucket weighs the asphalt that is pumped into the bucket from the supply tank. An adjustable suction pipe, lowered into the weigh-bucket to the proper depth, regulates the amount of asphalt delivered to the pugmill.

Pugmill

The aggregates and asphalt are blended into a smooth mixture by the paddles of the dyna-mix pugmill. The materials are constantly, rapidly, and repeatedly moved up and down as well as back and forth in the pugmill.

Discharge Gate

Little time is lost in discharging a completed batch through the hydraulically actuated discharge gate. There is no segregation of materials. The gate opens across the entire length of the paddle shafts and across the width (distance between the paddle shaft centers) of the pugmill. Being relatively large, the gate opening permits access from the bottom for maintenance and replacement of parts.

Plant Automation

The batch asphalt plant is almost completely self-acting. After mix proportions and timers are set and the plant is started, it repeats the weighing and mixing cycles until stopped by the operator or until a shortage of material or some out-of-ordinary event causes the plant to shutdown itself.

The manufacturer's operator's manual gives details on the setup and adjustment of the plant's automatic equipment. You must check the accuracy and adjustment of this equipment, particularly the aggregate scales, asphalt scales or meters, batching controls, and recording equipment (if used). This should result in trouble-free production. Moreover, the entire plant should be checked periodically to insure the finished product is up to specification.

INSPECTION AND ADJUSTMENT OF PAVING EQUIPMENT

Before paving operations begin, a careful inspection should be made of equipment to be used. Specifications normally require that the equipment be in good mechanical condition, properly adjusted, and free from wear which would impair the quality of work. Some of the equipment items which should be observed and checked are the asphalt distributor, motor grader, windrowing equipment, paver, rollers, and hauling equipment.

In checking the asphalt distributor, insure that (1) it complies with specifications; (2) the heaters and pumps are in good working order; (3) all gages and measuring devices, such as the tachometer and measuring stick, are properly calibrated; and (4) spray bars and nozzles are unclogged and set for proper application of asphalt.

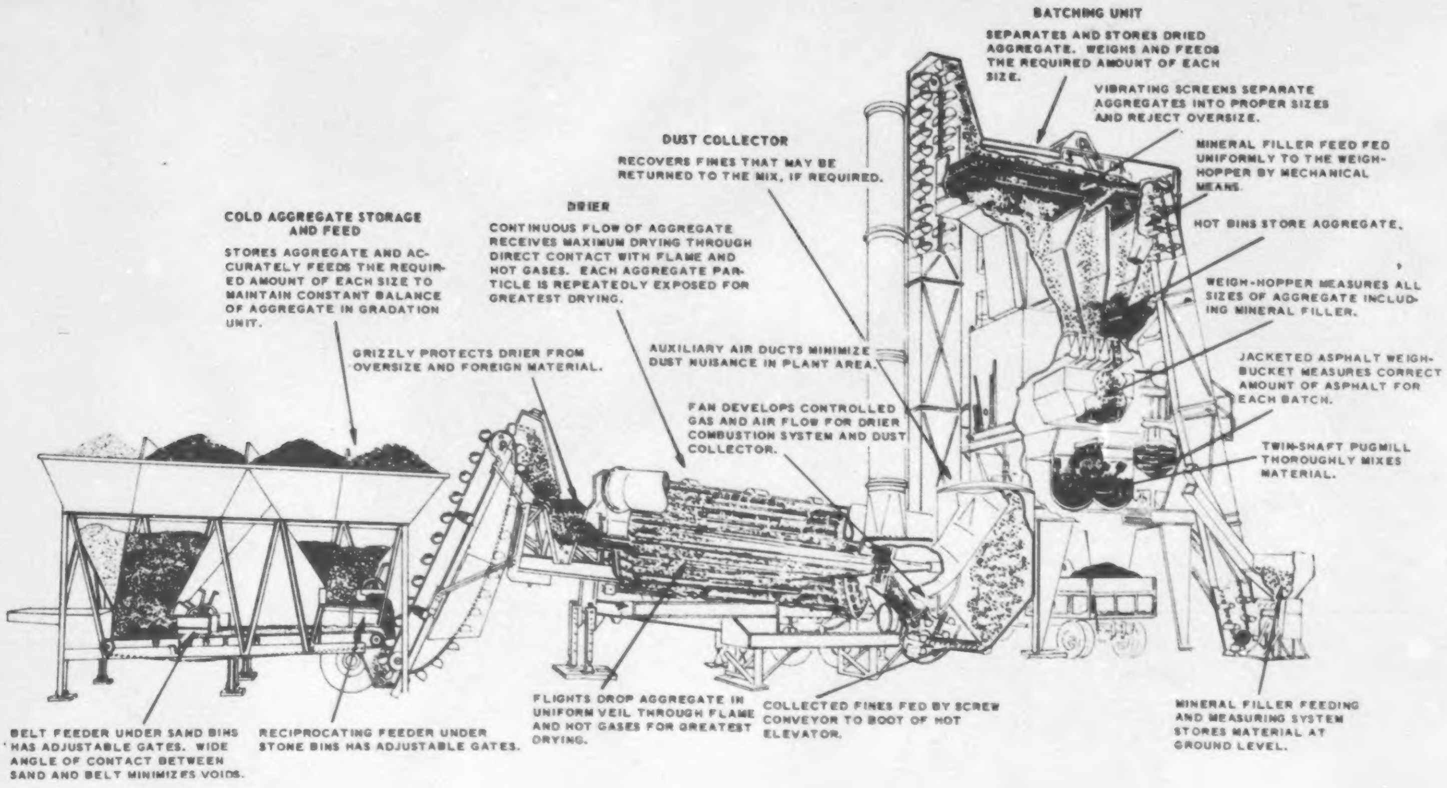

BATCHING UNIT
SEPARATES AND STORES DRIED AGGREGATE. WEIGHS AND FEEDS THE REQUIRED AMOUNT OF EACH SIZE.
VIBRATING SCREENS SEPARATE AGGREGATES INTO PROPER SIZES AND REJECT OVERSIZE.
DUST COLLECTOR
RECOVERS FINES THAT MAY BE RETURNED TO THE MIX, IF REQUIRED.
MINERAL FILLER FEED FED UNIFORMLY TO THE WEIGH-HOPPER BY MECHANICAL MEANS.
DRIER
CONTINUOUS FLOW OF AGGREGATE RECEIVES MAXIMUM DRYING THROUGH DIRECT CONTACT WITH FLAME AND HOT GASES. EACH AGGREGATE PARTICLE IS REPEATEDLY EXPOSED FOR GREATEST DRYING.
COLD AGGREGATE STORAGE AND FEED
STORES AGGREGATE AND ACCURATELY FEEDS THE REQUIRED AMOUNT OF EACH SIZE TO MAINTAIN CONSTANT BALANCE OF AGGREGATE IN GRADATION UNIT.
HOT BINS STORE AGGREGATE.
WEIGH-HOPPER MEASURES ALL SIZES OF AGGREGATE INCLUDING MINERAL FILLER.
AUXILIARY AIR DUCTS MINIMIZE DUST NUISANCE IN PLANT AREA.
GRIZZLY PROTECTS DRIER FROM OVERSIZE AND FOREIGN MATERIAL.
JACKETED ASPHALT WEIGH-BUCKET MEASURES CORRECT AMOUNT OF ASPHALT FOR EACH BATCH.
FAN DEVELOPS CONTROLLED GAS AND AIR FLOW FOR DRIER COMBUSTION SYSTEM AND DUST COLLECTOR.
TWIN-SHAFT PUGMILL THOROUGHLY MIXES MATERIAL.
FLIGHTS DROP AGGREGATE IN UNIFORM VEIL THROUGH FLAME AND HOT GASES FOR GREATEST DRYING.
COLLECTED FINES FED BY SCREW CONVEYOR TO BOOT OF HOT ELEVATOR.
MINERAL FILLER FEEDING AND MEASURING SYSTEM STORES MATERIAL AT GROUND LEVEL.
BELT FEEDER UNDER SAND BINS HAS ADJUSTABLE GATES. WIDE ANGLE OF CONTACT BETWEEN SAND AND BELT MINIMIZES VOIDS.
RECIPROCATING FEEDER UNDER STONE BINS HAS ADJUSTABLE GATES.

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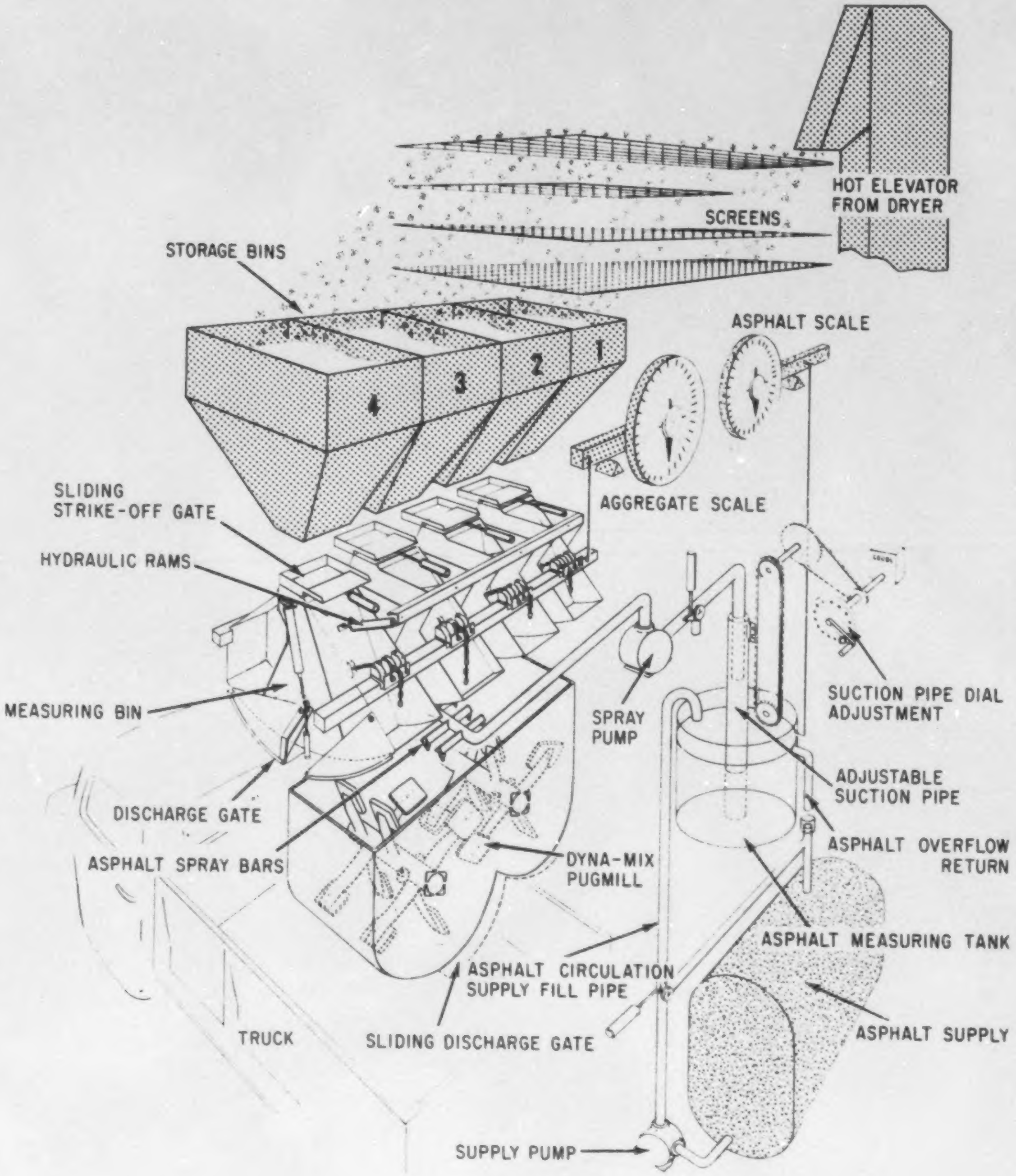
Figure 5-59.—Batch asphalt plant.


HOT ELEVATOR FROM DRYER
SCREENS
STORAGE BINS
1
2
3
4
ASPHALT SCALE
AGGREGATE SCALE
SLIDING STRIKE-OFF GATE
HYDRAULIC RAMS
LEVEL
SUCTION PIPE DIAL ADJUSTMENT
MEASURING BIN
SPRAY PUMP
ADJUSTABLE SUCTION PIPE
DISCHARGE GATE
ASPHALT OVERFLOW RETURN
ASPHALT SPRAY BARS
DYNA-MIX PUGMILL
ASPHALT MEASURING TANK
ASPHALT CIRCULATION SUPPLY FILL PIPE
ASPHALT SUPPLY
TRUCK
SLIDING DISCHARGE GATE
SUPPLY PUMP

143.293

Figure 5-60.—Schematic of aggregate, asphalt, and pugmill sections of a batch asphalt plant.

In regards to the motor grader, see that (1) it complies with specifications; (2) the cutting edge of the blade is straight and sharp; (3) all joints and linkages of the suspension system are snug and free from excessive wear; (4) all controls respond quickly and accurately when actuated and hold the position when set; and (5) all automatic controls, if the grader is so equipped, are properly adjusted.

Check the windrowing equipment to insure that (1) it complies with specifications; and (2) all fasteners and strike-off surfaces are free from excessive wear.

In checking the paver, insure that (1) it complies with specifications; (2) the governor on the engine is operating properly; (3) the slat feeders, the hopper gates, and the spreader screws are in good condition and adjustment; (4) the crawlers are adjusted properly; (5) the pneumatic tires (if so equipped) contain the correct and uniform air pressure; (6) the screed heater is working properly; (7) the tamper bars are free of excessive wear, adjusted for stroke, and the nose of the screed plate; (8) the surfaces of the screed plates and screed vibrators are true and in good condition, and the oscillating screed is in the proper position with respect to the vibrating compactor; and (9) the mat thickness and crown controls are in good condition and adjustment.

All rollers proposed for use on a project should be checked to insure that (1) each roller complies with project specifications; (2) the total weight of each roller is within the job tolerance; (3) the weights per inch of width of steel wheel rollers comply with specifications; (4) the average contact pressure of pneumatic-tired rollers comply with specifications; (5) each roller will start, stop, and reverse smoothly; (6) all steel wheels are straight across and free from grooves or pits; (7) wheel bearings are free from excessive wear; (8) scrapers, wetting pads, and sprinkler system on each roller are in good condition; and (9) vibrators, where applicable, are in good condition and adjustment.

In regards to hauling equipment, see that (1) truck beds are properly coated, smooth, and free from holes and depressions; (2) all trucks are equipped for cold weather or long hauls by having truck beds insulated, as well as equipped with tarpaulins; and (3) contact between the trucks and pavers is maintained without interference.

Adequate handtools with the proper equipment for cleaning and heating them should be on hand before paving starts. All incidental equipment should be inspected for proper condition to do the job intended.

Incidental tools include:

1. Rakes.
2. Shovels.
3. Lutes.
4. Tool heating torch.
5. Cleaning equipment.
6. Hand tampers.
7. Small mechanical vibrating compactors, there are considerable areas which might require tamping.
8. Blocks and shims for supporting the screed of the paver when beginning operations.
9. Rope, canvas, and timbers for construction of joints at ends of runs.
10. Joint cutting and painting tools.
11. Straightedge.

Construction with bituminous materials involves several hazards. One of the most serious dangers is associated with the heating required to convert solid or semisolid bituminous materials to a degree of fluidity which will permit their application and/or mixing. As a safety measure, make sure fire extinguishing equipment (foam type) is present at all times.

It is your responsibility to instruct your operators to ALWAYS extinguish burners on the asphalt distributor before attempting to spray bituminous material. When spraying starts, see that personnel stand at least 25 feet clear of the spray bar; spray bars have been known to blow open or rip with sudden pressure of heated materials.

Caution your operators to remember that bituminous material must be heated to a high temperature, and any of this hot material coming in contact with the skin will leave a serious burn. When your crew is heating bituminous material, be sure temperatures are checked frequently to see that the suggested temperature, as shown in table 5-9 is not exceeded. Remember that most of the flash

Table 5-9.—Suggested Temperatures for Uses of Asphalt

Type and Grade of Asphalt	Pugmill Mixing Temperature of Aggregates*	Distributor Spraying Temperature
Asphalt Cements		
(For Open-Graded Mixes, Types I & II)**		
40-50	225-310°F	
60-70	225-305°F	
85-100	225-300°F	
120-150	225-300°F	
200-300	225-300°F	
(For Dense-Graded Mixes, Types III-VIII)**		
40-50	275-350°F	
60-70	265-330°F	
85-100	255-325°F	
120-150	245-325°F	
200-300	225-300°F	
(For Distributor Spray Applications)		
40-50***		300-410°F
60-70***		295-405°F
85-100		290-400°F
120-150		285-395°F
200-300		275-385°F
Liquid Asphalts		
RC, MC, and SC Grades		
30	60-105°F	
70	95-140°F	
250	135-175°F	
800	165-205°F	
3000	200-240°F	
Asphalt Emulsions		
RS-1	****	75-130°F
RS-2	****	110-160°F
MS-2	50-140°F	100-160°F
SS-1	50-140°F	75-130°F
SS-1h	50-140°F	75-130°F
RS-2K	****	75-130°F
RS-3K	****	110-160°F
CM-K	50-140°F	100-160°F
SM-K	50-140°F	100-160°F
SS-K	50-140°F	75-130°F
SS-Kh	50-140°F	75-130°F

*The temperature of the aggregates and asphalt immediately before mixing should be approximately that of the completed batch.

**Mix Type III is intermediate between dense- and open-graded mixes. As the gradation of the mix changes from dense-graded to open-gradec the mixing temperature should be lowered accordingly.

***Not normally used for spray applications in pavement construction.

****Not used for mixing.

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points are exceeded before bituminous materials reach spraying or working temperature; therefore, additional caution must be exercised to prevent the exposure of the rising fumes to an open flame or spark. In addition, open flames must not be used to inspect or examine drums, distributors, or other containers in which bituminous materials have been stored.

When your operators and crewmembers are handling asphalt that is being processed, see that they wear loose, heavy clothing—in good condition. Clothing worn should be closed at the neck, sleeves rolled down over the top of gloves, and trousers (without cuffs) extending well down over the top of shoes (safety type). Goggles should be worn to prevent eye burn from bubbling or splashing asphalt. In addition, have your crewmembers wear safety hats at all times.

When you and your crew are working in a congested traffic area, insure that signs and warning devices are placed conspicuously on the project. In addition, a flagman, dressed in safety attire, should be assigned to aid in traffic control.

Check guards, safety devices, and so on, which have been placed over moving parts of equipment and machinery for the protection of the operators. These protection devices should not be removed except for the purpose of making immediate repairs, adjustments, or lubrication, and then, only after the power has been shut off. All guards and safety devices must be replaced immediately after completion of any repairs, adjustments, or lubrication by either your operators or maintenance personnel.

Instruct your crew to keep the area around mixing plants clean and clear of any waste materials.

Machinery and mechanized equipment must be operated only by qualified and authorized personnel. Make sure the equipment is operated in a manner that will not endanger other personnel or property.

When operating paving equipment, instruct the operators to hold frequent inspections of running mechanisms and attachments including such items as the power train, power plant, transmission, tracks, controls, loading and unloading warning devices, and receiving hoppers.

In applying paving materials, crewmembers often become so occupied with their particular job that they are unaware of equipment operating near them. For this reason, assign, on a rotating basis, a crewmember as your safety inspector to insure that safety precautions are observed within the assigned working areas. In addition, the safety inspector should hold short (approximately 5 to 15 minutes) safety meetings, called Stand-Up Safety Meetings, during which the crew is briefed of hazards and precautions relating to the current work project being completed.

Major Divisions (1)	(2)	Symbol Letter (3)	Hatching (4)	Color (5)	Name (6)	Value as Subgrade When Not Subject to Frost Action (7)	Value as Subbase When Not Subject to Frost Action (8)	Value as Base When Not Subject to Frost Action (9)
COARSE-GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	⁘	Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Excellent	Good
		GP	⁘		Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Good	Fair to good
		GM d	▥	Yellow	Silty gravels, gravel-sand-silt mixtures	Good to excellent	Good	Fair to good
		GM u				Good	Fair	Poor to not suitable
		GC	▨		Clayey gravels, gravel-sand-clay mixtures	Good	Fair	Poor to not suitable
	SAND AND SANDY SOILS	SW	⁘	Red	Well-graded sands or gravelly sands, little or no fines	Good	Fair to good	Poor
		SP	⁘		Poorly graded sands or gravelly sands, little or no fines	Fair to good	Fair	Poor to not suitable
		SM d	▥	Yellow	Silty sands, sand-silt mixtures	Fair to good	Fair to good	Poor
		SM u				Fair	Poor to fair	Not suitable
		SC	▨		Clayey sands, sand-clay mixtures	Poor to fair	Poor	Not suitable
FINE-GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML	▥	Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor to fair	Not suitable	Not suitable
		CL	▨		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Poor to fair	Not suitable	Not suitable
		OL	▥		Organic silts and organic silt-clays of low plasticity	Poor	Not suitable	Not suitable
	SILTS AND CLAYS LL IS GREATER THAN 50	MH	▥	Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable	Not suitable
		CH	▨		Inorganic clays of high plasticity, fat clays	Poor to fair	Not suitable	Not suitable
		OH	▩		Organic clays of medium to high plasticity, organic silts	Poor to very poor	Not suitable	Not suitable
HIGHLY ORGANIC SOILS		Pt	≋	Orange	Peat and other highly organic soils	Not suitable	Not suitable	Not suitable

Table 5-3.—Characteristics Pertinent to Roa

Potential Frost Action (10)	Compressibility and Expansion (11)	Drainage Characteristics (12)	Compaction Equipment (13)	Unit Dry Weight lb. per cu. ft. (14)	Typical Design Values	
					CBR (15)	Subgrade Modulus k lb. per cu. in. (16)
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	125-140	40-80	300-500
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	110-140	30-60	300-500
Slight to medium	Very slight	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	125-145	40-60	300-500
Slight to medium	Slight	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	115-135	20-30	200-500
Slight to medium	Slight	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	130-145	20-40	200-500
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller	110-130	20-40	200-400
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber tired roller	105-135	10-40	150-400
Slight to high	Very slight	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	120-135	15-40	150-400
Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-130	10-20	100-300
Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-135	5-20	100-300
Medium to very high	Slight to medium	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	90-130	15 or less	100-200
Medium to high	Medium	Practically impervious	Rubber-tired roller, sheepsfoot roller	90-130	15 or less	50-150
Medium to high	Medium to high	Poor	Rubber-tired roller, sheepsfoot roller	90-105	5 or less	50-100
Medium to very high	High	Fair to poor	Sheepsfoot roller, rubber-tired roller	80-105	10 or less	50-100
Medium	High	Practically impervious	Sheepsfoot roller, rubber-tired roller	90-115	15 or less	50-150
Medium	High	Practically impervious	Sheepsfoot roller, rubber-tired roller	80-110	5 or less	25-100
Slight	Very high	Fair to poor	Compaction not practical			

Note:

1. Column 3, division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is on basis of Atterberg limits; suffix d (e.g., GMd) will be used when the liquid limit is 25 or less and the plasticity index is 5 or less; the suffix u will be used otherwise.
2. In column 13, the equipment listed will usually produce the required densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled. In some instances, several types of equipment are listed because variable soil characteristics within a given soil group may require different equipment. In some instances, a combination of two types may be necessary.
   a. Processed base materials and other angular materials. Steel-wheeled and rubber-tired rollers are recommended for hard, angular materials with limited fines or screenings. Rubber-tired equipment is recommended for softer materials subject to degradation.
   b. Finishing. Rubber-tired equipment is recommended for rolling during final shaping operations for most soils and processed materials.
   c. Equipment size. The following sizes of equipment are necessary to assure the high densities required for airfield construction:
      Crawler-type tractor—total weight in excess of 30,000 lb.
      Rubber-tired equipment—wheel load in excess of 15,000 lb., wheel loads as high as 40,000 lb. may be necessary to obtain the required densities for some materials (based on contact pressure of approximately 65 to 150 psi).
      Sheepsfoot roller—unit pressure (on 6- to 12-sq.-in. foot) to be in excess of 250 psi and unit pressures as high as 650 psi may be necessary to obtain the required densities for some materials. The area of the feet should be at least 5 per cent of the total peripheral area of the drum, using the diameter measured to the faces of the feet.
3. Column 14, unit dry weights are for compacted soil at optimum moisture content for modified AASHO compaction effort.
4. In column 15, the maximum value that can be used in design of airfields is, in some cases, limited by gradation and plasticity requirements.

ds and Airfields

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CHAPTER 6

PITS AND QUARRIES

This chapter provides information on the selection and operations of pits and quarries. It describes basic principles of site selection and preparation, methods and techniques of developing pits and quarries, and basic setups for arrangements of the equipment required to process quarry rock and materials extracted from pits.

Pits are excavations made at the earth's surface in unconsolidated materials, such as clay, sand, gravel, coral, and laterite. They are sites from which suitable construction materials are obtained in quantity, being removed or extracted from the surface without the use of blasting. Alluvial or stream-deposited gravel pits yield gravel that is usually clean and free of clay and humus, and therefore desirable for concrete and bituminous work. Bank or hill gravel pits yield a clayey gravel, which is desirable for road or runway surfacing because of its binding qualities. Gravel is also used for base courses and fills. Soil (other than sand and gravel) selected for use in embankments, fills, and subgrades is obtained from borrow pits. Miscellaneous pits contain mixed tailings, slag, cinders or the like, which are also used for road or runway surfacing and as aggregates.

Quarries are sites where large open excavations are made for the purpose of extracting or removing rock in its natural state by drilling, cutting, and blasting. In some cases, it may be possible to remove the rock by use of rippers and power shovels. The main types of rocks obtained from quarries are igneous and metamorphic, such as trap rock, granite, diorite, geneiss, quartize, and certain shales. Military quarries are generally open faced, which means the vertical surface of the rock is exposed. Since seldom used in its inplace state, quarry rock is processed with mobile equipment that crushes, screens, and washes.

SITE SELECTION

Before a pit or quarry is located, an investigation of the site has established that suitable construction materials are available in adequate amounts and that the excavation can be worked efficiently with available equipment. Whenever possible, existing pits and quarries are used because (1) the quantity and quality of materials can easily be determined, (2) good haul and access roads are probably already built, (3) less effort can be spent on removal of overburden, and (4) facilities, such as ramps, hoppers, bins, power, and water, are generally available.

The chosen site should be as close as possible to the construction project and convenient to good routes of transportation. This will allow for more efficient hauling by decreasing the length of haul roads. Pit and quarry haulage is usually accomplished with equipment, such as dump trucks, trucks-off-highway, and tractor-drawn or motorized scrapers.

SITE PREPARATION

Preparation of a new site should start immediately after its location has been selected. Preparatory work includes making an operations plan, clearing the site, removing overburden, draining the site, building roads, and loading ramps, and installing processing equipment.

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OPERATIONS PLAN

The operations plan is prepared before any earth is moved. The plan includes the limits of the site to be developed, methods of excavation, equipment to be used, number of personnel required, and locations of roads, structures, and support equipment. Also, plans for traffic control and drainage are established.

CLEARING THE SITE

If the area is wooded, the first operation in preparing the site is to clear all timber, standing or fallen. If camouflage is necessary, trees or brush outside the designated cleared area should not be removed.

Construction equipment is usually the most rapid and efficient means of clearing. Use of the equipment is limited only by unusually large trees and stumps, terrain which affects their maneuverability, and maintenance requirements. This equipment includes bulldozers, tractor-mounted clearing units, winches, power saws, rippers, motor graders, and scrapers. In addition, handtools are used in certain clearing operations. The selection of equipment is usually limited to that which is available on the job. However, under certain conditions a specific type of equipment is most efficient in clearing an area and should be used.

Brush may be disposed of by burning on the site, but timber should be moved clear of the perimeter of the site. Timber of suitable dimensions should be stockpiled for possible use in construction of loading ramps. All stumps, roots, boulders, vegetation, and rubbish must be excavated and moved clear of the site.

OVERBURDEN

Overburden is usually removed from a pit or quarry site by a continuous process of stripping. The methods and equipment used in removing overburden will vary with the type of excavation planned, depth of overburden, and distance that the overburden must be moved. It may be advantageous to leave inplace the overburden at military quarry sites and blast it with the rock to provide binder for road building materials. Removal is coordinated with excavation to provide a continuously cleared area. The spoil should be dumped in a remote area to avoid double handling. On hillside locations, the spoil should be placed in banks, located on the downhill side, outside the working area.

All overburden is not necessarily waste. Some, is suitable for filling, building access roads, and leveling stockpile and equipment sites.

In excavating aggregates for concrete, bituminous mixtures, or base courses, the overburden must be removed while the aggregates are processed. Frozen material is loosened either with a ripper or explosives. Overburden should be kept cleared at least 50 feet back from the top of the face of a quarry or pit to prevent rock and other material from falling on personnel working near the top of the face. Also it should be cleared far enough back from the top so that the equipment being used to clear the overburden does not interfere with drilling operations.

DRAINAGE

Adequate drainage is essential to the operation of a pit or quarry. Alluvial gravel pits may be worked wet or dry, depending on water levels. Borrow pits and quarries are normally worked dry.

Drainage facilities are installed as early as possible so that the site will be dry when work starts. The means of drainage depends mainly on the location and the amount of water to be eliminated. Hillside locations are easy to drain by an interceptor ditch made along the uphill side with a scraper, dozer, or grader. When the floor of a site is below ground level, both surface and seepage water must be disposed of. If open ditches cannot be dug to take advantage of gravity flow, all water is directed to a sump hole. A slight slope on the site floor must be maintained at all times to permit water to drain away from the working face of the site.

ROADS

Construction of the access roads should start as soon as the operations plan is completed so that they will be ready when the pit and quarry equipment arrives. They are designed for all-weather operation under the heaviest loads anticipated. They follow the shortest and easiest routes that will satisfy the traffic control plan. To speed up hauling, sharp curves are avoided and grades kept as low as possible. Ten percent is the maximum grade for truck operation, whereas tractors and graders can climb 20-percent grades for short distances. Except for the loop at the loading site, access roads provide one-way traffic; one route to enter, and another to haul out. Enough space is left between haul roads and borrow pits to avoid traffic hazards.

LOADING RAMPS

A loading ramp is a structure built for the purpose of loading excavated material into trucks with earthmoving equipment at sites where power shovels or clamshells are unavailable. An elementary type of loading ramp is the plain chute illustrated in figure 6-1. Each ramp must be able to support the heaviest equipment used, plus an impact factor of 50 percent, and approximately 20 tons of material.

INSTALLING PROCESSING EQUIPMENT

The work of installing processing equipment is usually started after the haul roads have been completed and while overburden is being cleared. Each crushing, screening, and washing plant should be supported by a concrete foundation to prevent settling. If concrete is not available, the foundation is made of heavy construction mats or log cribbing and the earth is compacted hard. The foundation should be 10 feet longer than the wheelbase of the plant and wider by 1 1/3 times the width of the plant. Mobile plants on a rock-floored quarry do not require elaborate foundations. However, they must be securely blocked and cribbed.

The processing plant should be located as close as practicable to the face of the pit or quarry, but far enough away to prevent its being damaged by falling rock or blasting. When possible, the crusher must be set up so that its engine, motors, and operator are protected against the effects of dust. If this can't be done,

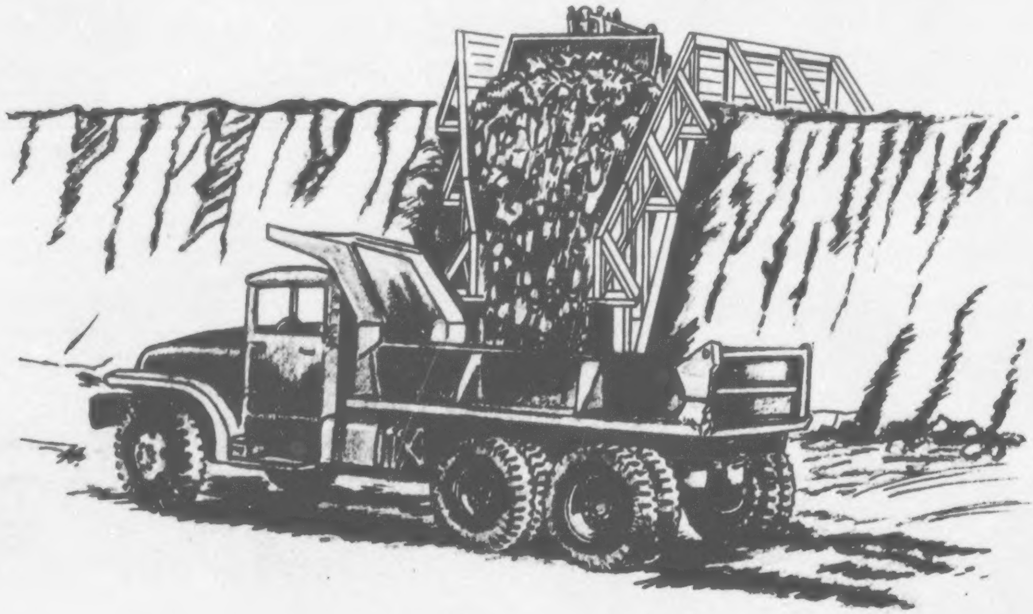

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Figure 6-1.—Simple chute loading ramp.

water sprays or other means are used to minimize the dust problem. This includes taking advantage of the direction of the prevailing wind. Make certain that guardrails and protective shields are properly secured inplace before operating this equipment.

PIT OPERATION

Sand, gravel, and other construction materials are extracted from pits with tractor-drawn or motorized scrapers that can move huge volumes of material in a relatively short period of time. The material is removed from the floor of the pit in successive thin layers over its entire width.

During excavation, scrapers should be carefully spotted to maintain an even downgrade and prevent cutting holes below the general level of the pit floor. If the pit is longer than 100 feet in the direction of loading, the scraper spots should be staggered along the length of the cut as well as across the width of the zone. Figure 6-2 depicts the layout and development of a scraper pit, with lines A-A and B-B showing the limits of the pit. Lines a-a and b-b divide the area into three zones, for current excavating, stripping, and clearing. Zone 1 is being excavated at the same time zone 2 is being stripped and zone 3 is being cleared. Three tractor-drawn scrapers in staggered formation load downhill in zone 1, while a dozer strips downhill in zone 2.

In consolidated gravels or soft rock, when scrapers assisted by pusher tractors will not pick up a heaping load in 150 feet, a ripper should be used to loosen the material, thereby increasing the loading efficiency. Rippers are operated downhill and an entire zone is ripped at one

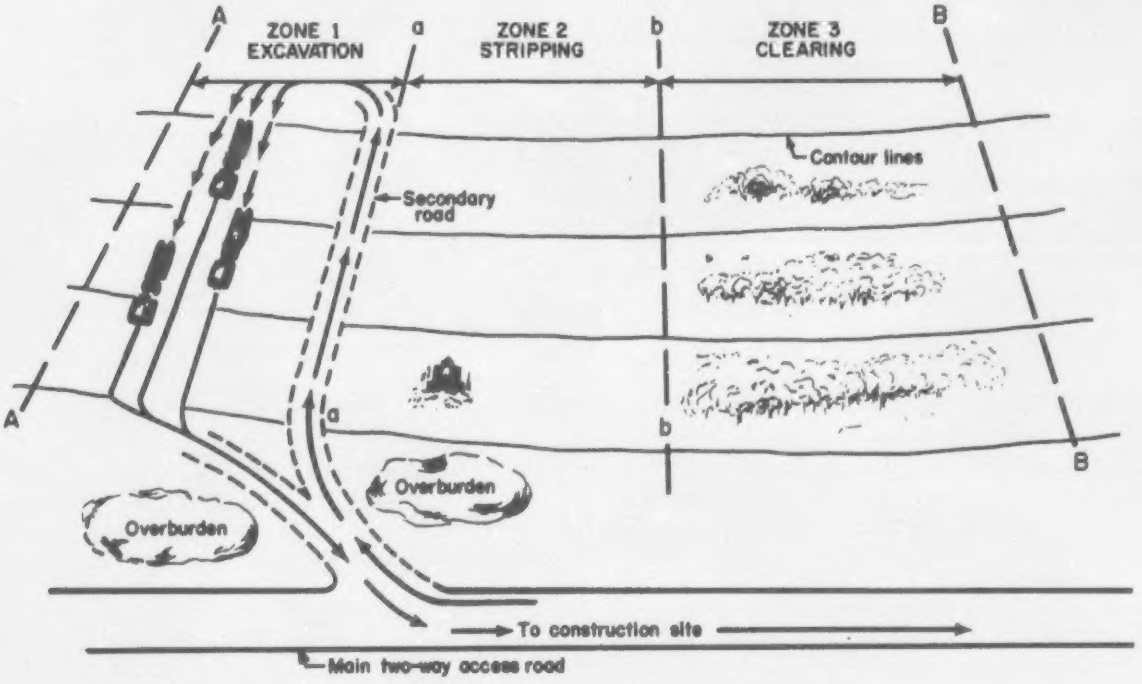

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Figure 6-2.—Layout and development of a scraper pit.

time while the scrapers are hauling from another zone.

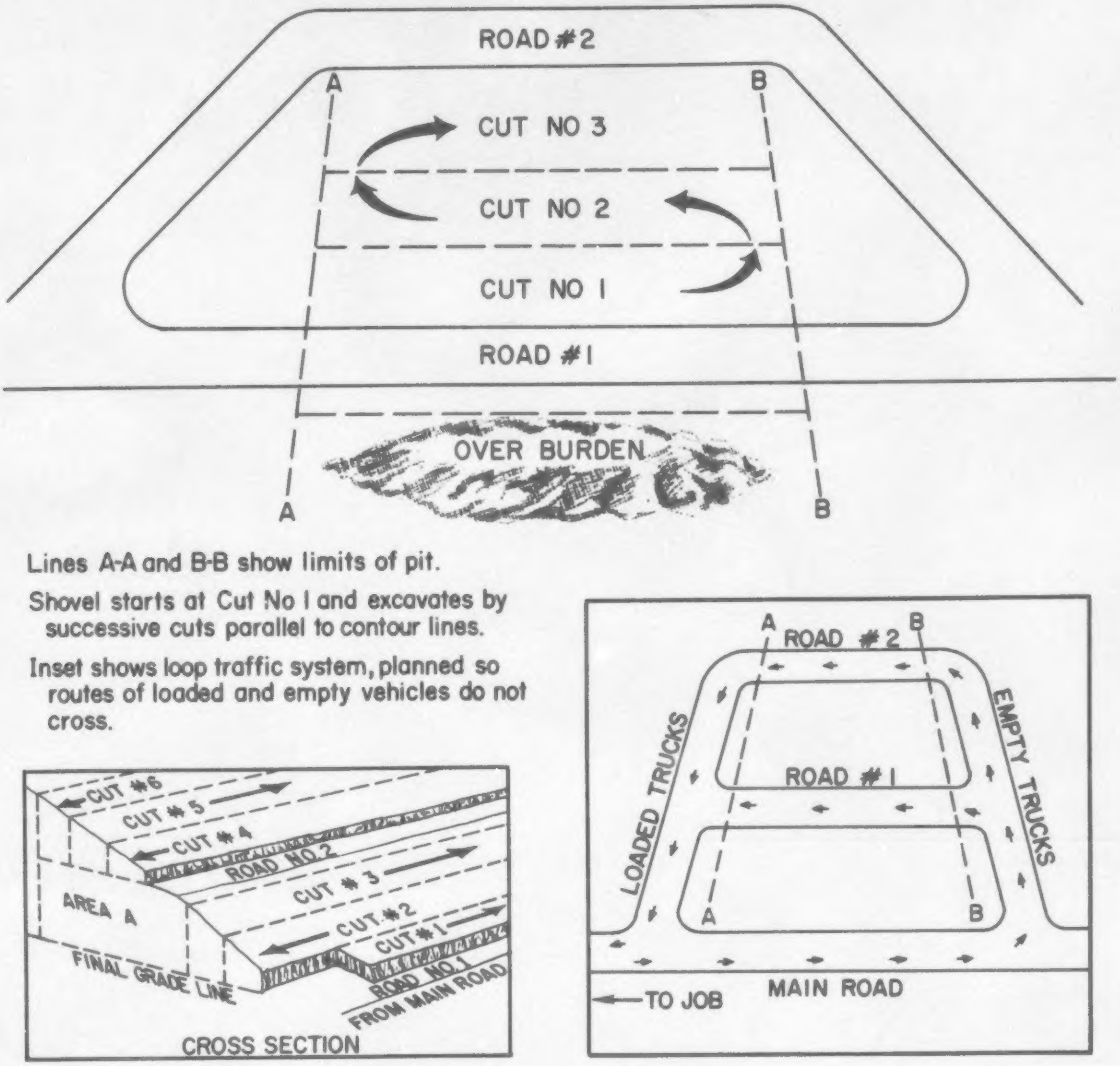
A shovel and truck combination is primarily used in pits consisting of above water gravel deposits, because, as a rule, required quantities are less and hauling distances are greater than for earth borrow pits. The power shovel is particularly adapted to hillside deposit removal. Power shovels may also be profitably adapted to horizontal deposits provided a working face of the proper height is maintained. When faces are too high (over two-thirds the boom height), a dozer is sometimes used to feed the shovel from above to prevent dangerous overhang.

Deposits are excavated by power shovels on benches in successive cuts parallel to the contour lines (fig. 6-3). First, a road is cut and leveled with a dozer along the toe of the slope of a hill. Starting from this road, the shovel is used to cut into the bank until the shovel is off the road. The shovel is then still in position to reach trucks parked on the road. The first cut is completed, and a second cut is made while the trucks use the first cut as a road. When the shovel has advanced into the hill to a point at which the maximum working-face height is reached, a second road is dozed above the cut and a new bench started. When the second face reaches a maximum height, a third bench is started or the shovel is moved back to the first bench and that face advanced. When more than one shovel is used, several benches may be operated simultaneously. If the benches are of sufficient length and width, two or more shovels may be operated on the same bench. The floor of the benches should always be kept sloping slightly upward toward the face to provide drainage.

In level country, it is sometimes necessary to use power shovels to excavate material from deposits below the surrounding ground level. This applies particularly to gravel deposits where draining presents no problem. When deposits are sufficiently large, pits are best developed by the circular bench method illustrated in figure 6-4. Start the shovel digging on a downgrade of not over 10 percent, until it is working against a face of suitable height. When the initial cut is advanced by the shovel and the face is not more than 6 or 8 feet in height, trucks are kept on the surface for loading to keep the swing of the shovel as short as possible. When the initial cut is completed, the shovel widens the pit by making additional cuts. Trucks are spotted in the first cut for loading while the shovel is making the second cut, and so on. The shovel continues to dig deeper with each successive cut until the desired maximum height of face is reached. As the pit widens from successive cuts, it assumes a circular shape. Either loop traffic within the pit or one-way traffic may be established depending on gradient of entrance, outside traffic pattern, trafficability of pit floor, area of the pit, quantity of equipment in the pit, and other factors. If more shovels are available than can operate efficiently on the face around one level, then a second lower level is started inside the first, beginning near the first. Development of the second and succeeding levels is the same as that of the first.

Certain deposits, such as those of old streambed origin, are not wide enough for circular development. A similar method of operation involves development in straight line benches as shown in figure 6-5. The shovel or dozer digs the first cut to a depth sufficient to provide a desirable height of the working face. The cut is continued at this depth and trucks are loaded over the bank. Then the shovel reverses its direction, making a second cut alongside the first. The dozer is used to level the first cut for trucks. Succeeding excavation are made in parallel straight cuts. If the deposit is deep enough, even a second and third level can be developed, beginning at one side of the pit rather than in the center. The depth at which this deposit may be worked is usually limited by the elevation of the ground water table. Deep narrow deposits tend to develop faces of great height. Due caution MUST be exercised to avoid endangering personnel and equipment by cave-ins or slides.

The dragline is the most practical piece of construction equipment for underwater digging and is particularly adapted to submerged gravel pit operations. Draglines can efficiently recover sand, gravel, laterite, or coral from streambeds, lake bottoms, lagoons, and beaches. Figure 6-6


ROAD #2
A
B
CUT NO 3
CUT NO 2
CUT NO 1
ROAD #1
OVER BURDEN
A
B
CUT #6
CUT #5
CUT #4
ROAD NO.2
CUT #3
AREA A
CUT #2
CUT #1
FINAL GRADE LINE
ROAD NO.1
FROM MAIN ROAD
CROSS SECTION
A
B
ROAD #2
LOADED TRUCKS
EMPTY TRUCKS
ROAD #1
A
B
TO JOB
MAIN ROAD

Lines A-A and B-B show limits of pit.

Shovel starts at Cut No I and excavates by successive cuts parallel to contour lines.

Inset shows loop traffic system, planned so routes of loaded and empty vehicles do not cross.

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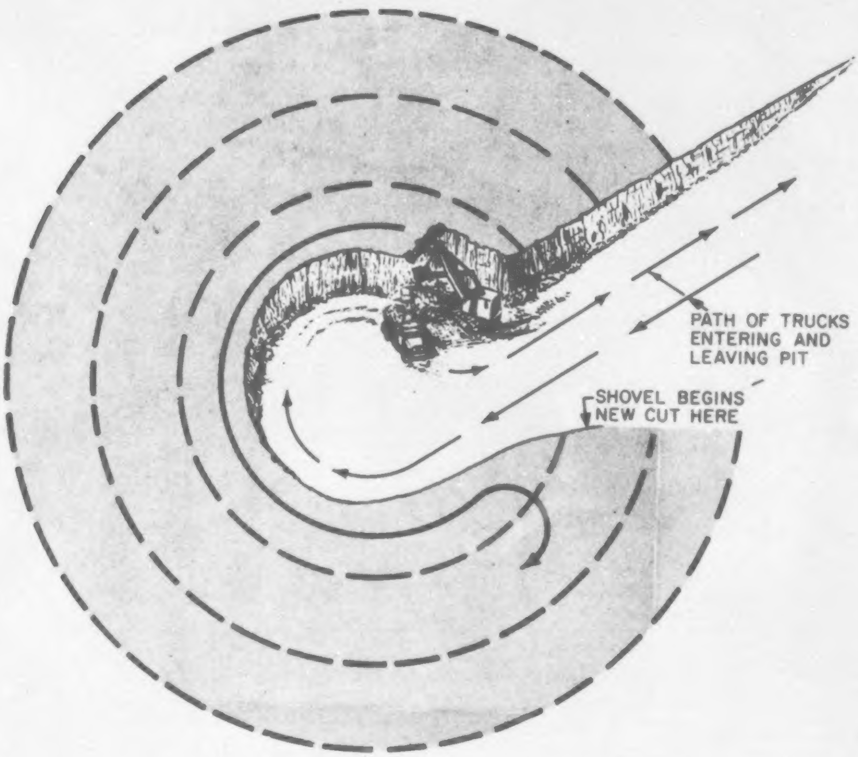
Figure 6-3.—Layout and development of hillside pit for power shovel operation.

depicts the layout and development of a pit being excavated with a dragline.

Clamshells are capable of excavating loose materials (sand, gravel, and crushed stone) at, above, or below ground level. They can also, raise and dump a load at heights equal to the distance from the tip of the boom to the ground less the length of the clamshell bucket, allowing adequate clearance for the bucket when opening.

Material removed from pits can seldom be used in its inplace state. In most cases, pit


PATH OF TRUCKS ENTERING AND LEAVING PIT
SHOVEL BEGINS NEW CUT HERE

115.348

Figure 6-4.–Layout and development of a subsurface pit using circular bench method.

material must be processed (crushed and screened) in order to meet job specifications. But before it can be processed, the material must be loaded and delivered to the processing equipment. Loading and delivery may require additional handling equipment, such as front-end loaders equipped with either a rollback bucket or 4-in-1 bucket; conveyors which may be used singly or in series to load vehicles, construction equipment, or hoppers from stockpile material, and bucket loaders consisting of a power-driven endless chain to which buckets are attached so that material is loaded on the upward travel of the chain and unloaded on the downward travel. This handling equipment is used to load stockpiled material into overhead hoppers and trucks.

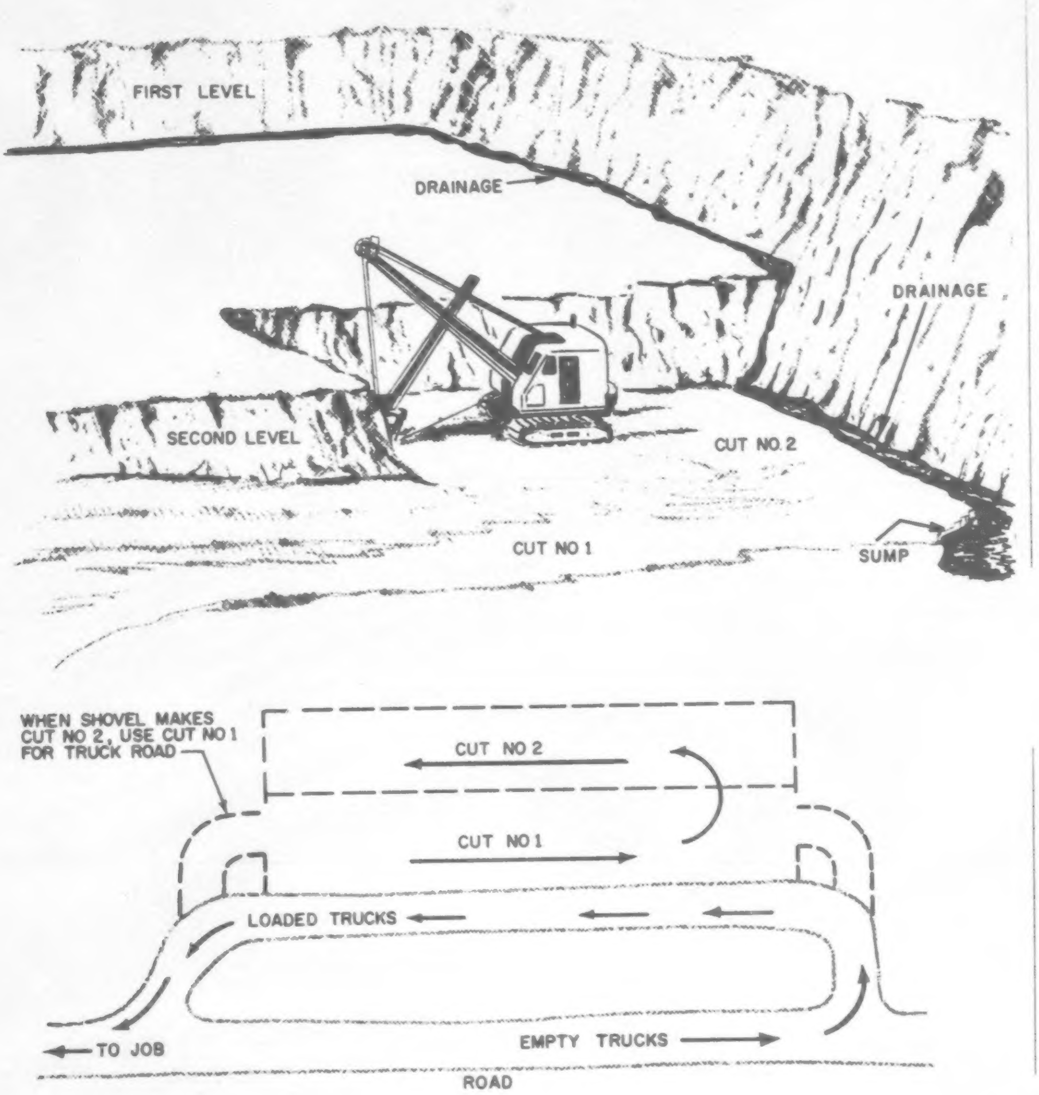
The production of any pit material that requires crushing and screening depends on the capacity of the processing equipment. The operation and uses of this equipment are described later.

QUARRY OPERATIONS

Quarrying involves not only extraction of material rock but also crushing and screening, which makes the rock suitable for use as construction material.

DEVELOPING A QUARRY

The layout of a quarry should provide a gravity flow of material from the face to the crusher, from the crusher to the storage bin, and

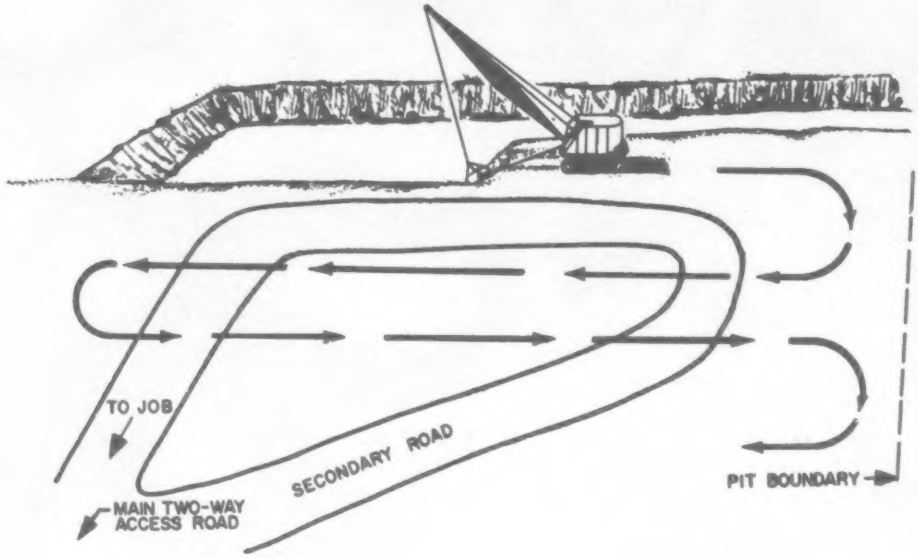

FIRST LEVEL
DRAINAGE
DRAINAGE
SECOND LEVEL
CUT NO. 2
CUT NO 1
SUMP
WHEN SHOVEL MAKES CUT NO 2, USE CUT NO 1 FOR TRUCK ROAD
CUT NO 2
CUT NO 1
LOADED TRUCKS
TO JOB
EMPTY TRUCKS
ROAD

115.349

Figure 6-5.—Layout and development of a subsurface pit using straight bench method.

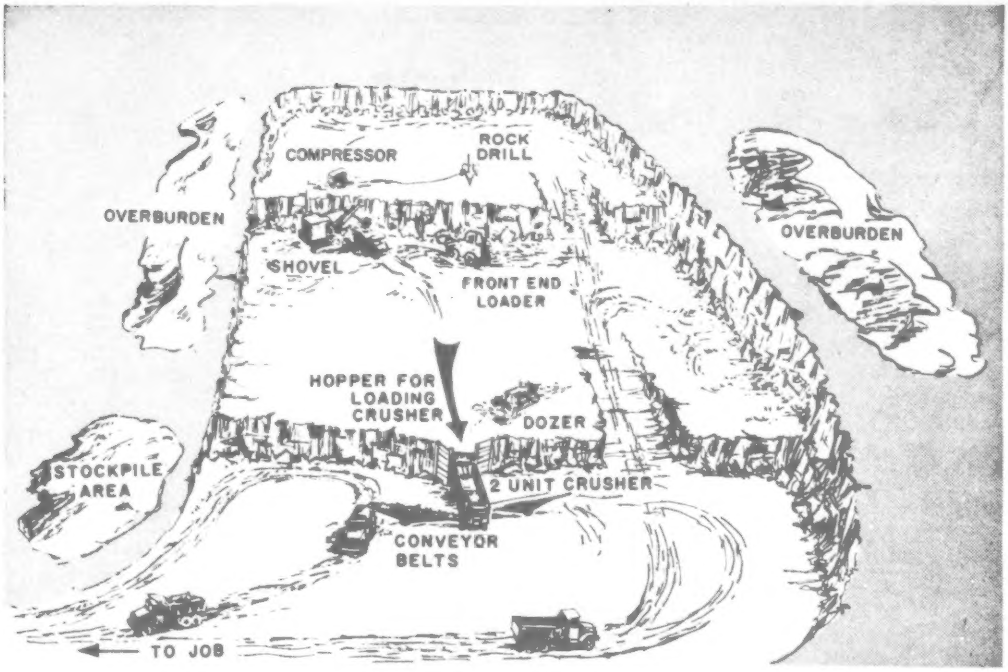
from the bin to the hauling equipment, as illustrated in figure 6-7. A quarry laid out in this manner assures that a maximum quantity of rock can be processed with a minimum of labor and equipment. In quarries laid out on the gravity-flow principle, the drainage problem is practically eliminated.

Military quarries are generally of the open-face type with the vertical surface of the rock exposed. Depending upon local conditions, they may be developed by the single or multiple bench method. Where the rock face is not exposed, core samples should be taken in a grid pattern so that rock formations can be plotted,


TO JOB
SECONDARY ROAD
MAIN TWO-WAY ACCESS ROAD
PIT BOUNDARY

115.350

Figure 6-6.–Layout and development of a subsurface pit using the dragline.

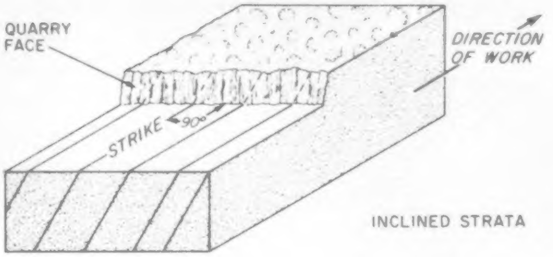

COMPRESSOR
ROCK DRILL
OVERBURDEN
OVERBURDEN
SHOVEL
FRONT END LOADER
HOPPER FOR LOADING CRUSHER
DOZER
STOCKPILE AREA
2 UNIT CRUSHER
CONVEYOR BELTS
TO JOB

115.358

Figure 6-7.–Typical quarry layout.

190

and lay of the strata, quality and quantity of the deposit, and depth of overburden can be determined. Should a rock formation be jointed or stratified, the layout of the quarry is determined by the strike (direction) of the formation; that is, the face of the quarry must be directed at right angles to the strike (fig. 6-8). This will insure a vertical or near vertical face with less chance of undercutting the face and creating a dangerous overhang.



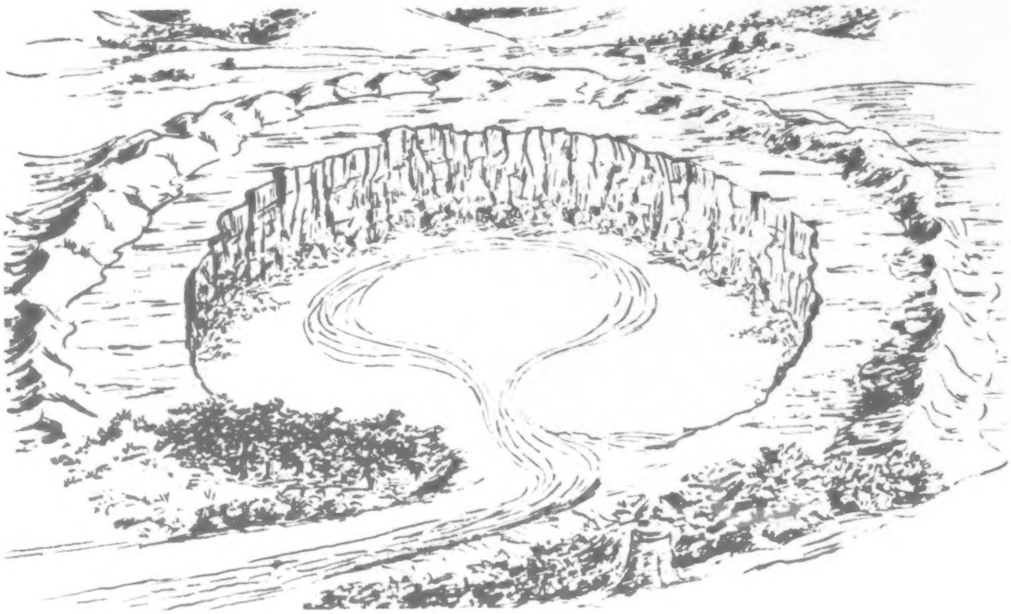
143.294

Figure 6-8.—Orientation of a quarry face.

A single bench quarry (fig. 6-9) is one having the entire floor on one level. The height of the bench worked in one operation varies from 8 to 30 feet, depending on the drilling equipment available, type of rock, magnitude of operation, and experience of the operating personnel. Military quarries are usually of the single bench type, since they offer greater safety and efficiency of operation. All operations are on one level, a greater amount of rock is shot at one blast, and less equipment is needed in the overall process. In addition, this type of quarry requires less training of the operating crews.

CAUTION: The blasting must be supervised and controlled directly by a qualified blaster. Also, all personnel working around blasting should wear hard hats, safety goggles, dust respirators, earplugs, and hard toe safety shoes.

Trial shots are made in both existing and new quarries prior to installing equipment to



115.359

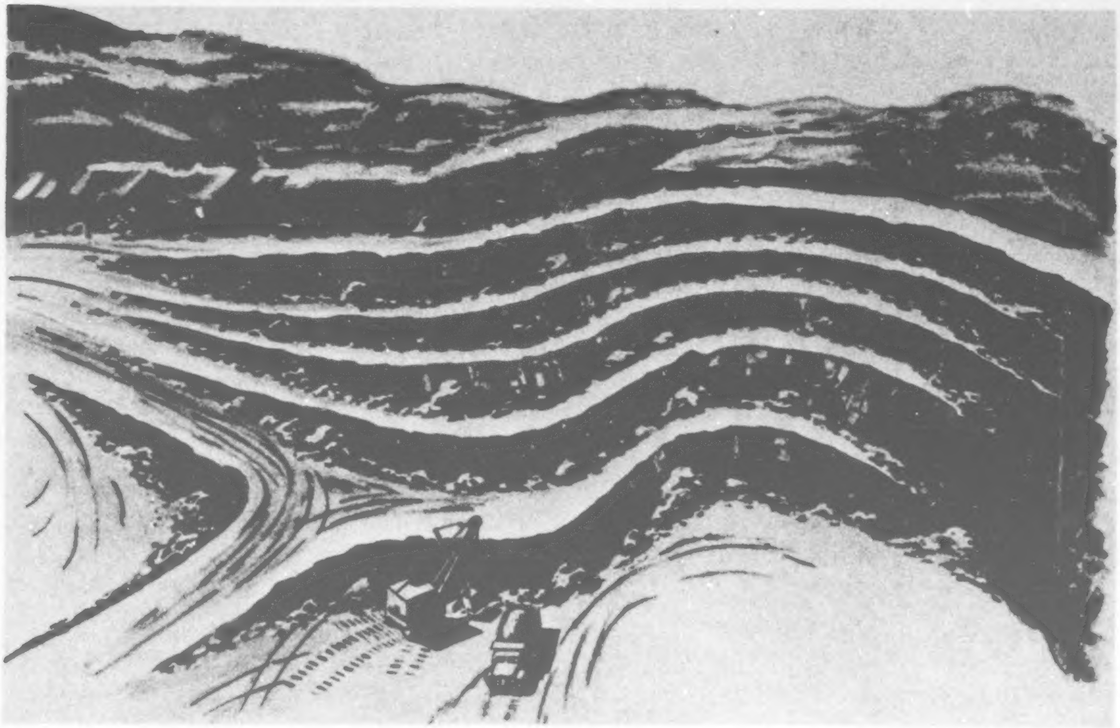
Figure 6-9.—Single bench quarry.

avoid possible damage to the equipment. Another consideration in the case of new quarries is that the trial shots will provide necessary ballast to construct access roads and foundations for the equipment.

A multiple bench quarry (fig. 6-10) is one having a series of ledges or terraces resembling steps. The highest bench is blasted and worked first. Then successively lower levels are simultaneously developed as the work progresses and as each bench is required. Quarries are developed by the multiple bench method when the face is too high for single shots, horizontal seams or separations are present, or deep and narrow deposits exist. This method of development permits equipment to be used simultaneously at more than one level. The height of each face is governed by the drilling equipment available. All benches must be made wide enough to permit use of equipment in removing the blasted rock (50 feet minimum). Multiple bench quarries make possible greater continuity of operation than single bench quarries. CAUTION: In developing a multibench quarry, blasting must be confined to only one bench at a time. Simultaneous blasting at several levels is NOT permitted under any circumstances.

PROCESSING QUARRY ROCK

All quarry equipment is subject to exceptionally hard wear due to the abrasive action of rock and rock dust. Therefore, the instructions contained in the manufacturer's maintenance and service manuals must be strictly followed. The equipment used in



115.360

Figure 6-10.—Multiple bench quarry.

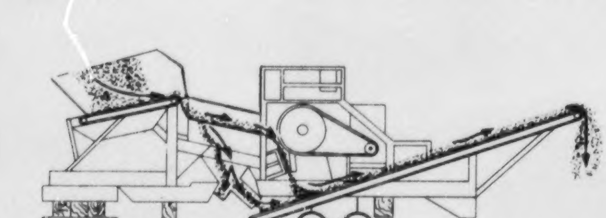
hard-rock quarries consists of bulldozers, air compressors, drills, drill steel and bits, blasting equipment, crushing and screening plant, loading and hauling equipment, and miscellaneous tools.

Equipment is available in the Naval Construction Force to enable construction units to meet their own aggregate production requirements. The SEABEES have a number of crushing plants varying in capacity output. A particular plant, classified medium-to-large, has a rated capacity of 75 tons per hour (TPH). This plant has two separate and distinct sets of equipment: the primary unit and secondary unit.

The primary unit carries out the first stage of reducing the quarry rock by crushing. It is also used to crush coarse gravel. The secondary unit is ordinarily used to process the crushed product.

The primary unit (fig. 6-11) consists of a 20" x 36" standard-type jaw crusher, a heavy duty apron-type feeder, a two deck vibrating grizzly, an under crusher delivery conveyor, a diesel power unit, and a running gear. The diesel engine powers the jaw assembly only. All other components are driven by individual electric motors. Make certain each electrically powered component is grounded. Power is usually supplied by a 100 KW diesel generator. The running gear is equipped with a fifth wheel and towing dolly.

Raw materials are deposited into the hopper of the heavy duty apron feeder which moves the material onto the deck of the vibrating grizzly. The rate of flow of the feeder belt is controlled by the operator using the "start" and "stop" buttons located on the control panel. As the material is moved out of the feed hopper, it is processed across a two-deck vibrating grizzly. The top deck is a bar-type screen with a 1-1/2-inch fixed opening. It screens out material smaller than 1-1/2 inches and routes the oversized material through the jaw chamber to be crushed. The second deck is of conventional wire mesh screen. The material retained on the bottom deck is routed via a chute to the under crusher conveyor, where it joins the jaw crusher product. This material can be directed through another chute (by closing a flop gate) and routed to a by-product stockpile. Likewise, the material passing the bottom screen may be included in the crusher product or discarded by manipulation of another flop gate. The vibrating grizzly prescreens material by passing the jaw crusher with material that is already down to size. It also drycleans the material by vibrating it vigorously; and by means of the flop gates, enables you to select and decide what to do with the smaller particles. Material which is oversized is routed through the jaw crusher where it is reduced in size and discharged onto the under crusher delivery conveyor belt.



115.361

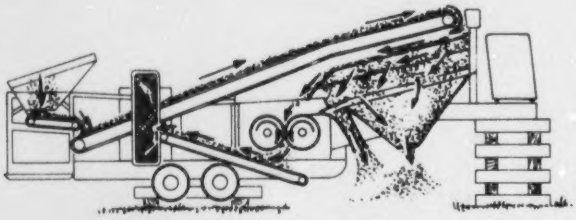
Figure 6-11.—Material flow through primary unit, 75 TPH crushing and screening plant.

The jaw crusher will produce at a rate of 55 to 185 TPH, depending upon the product setting and the toughness of the material being crushed. The maximum product setting is 5 inches and the minimum setting is 1-1/2 inches.

CAUTION: Keep all parts of the body out of the jaw cavity while operating or adjusting the jaws.

The secondary unit (fig. 6-12) consists of a reciprocating feed hopper, an over-crusher conveyor, a two deck vibrating screen, a dual roll crusher, an under crusher return conveyor, a revolving elevator wheel, a diesel power unit, and the running gear. The diesel engine drives the dual roll crusher assembly. All other components are driven by individual electric motors. Power is supplied by a 100-KW generator.

Material to be processed is introduced into the hopper of the reciprocating feeder. The rate of flow is controlled by the adjustable gate



115.362
Figure 6-12.–Material flow through secondary unit, 75 TPH crushing and screening plant.

opening. Material is deposited onto the over-crusher conveyor and carried to the feed end of the top screen. Material that has been crushed down to product size by the jaw crusher will pass the top screen. Oversized material will be retained on the top screen and directed through a dual roll crusher for further reduction. This material is then recirculated to the top screen by means of a return conveyor and a revolving elevator wheel. If any of this material is still too large to pass the top screen, it will be routed through the roll crusher again. This is known as a "closed circuit" crushing system. It is then obvious that the product setting on the roll crusher should be set at or slightly less than the top screen opening size. The material retained on the bottom screen is normally the product. It will be routed via a chute to a conveyor and delivered to the product stockpile. Material that is too small to meet product specifications will be screened out by the bottom screen and delivered to a by-product stockpile. The secondary unit includes a bar-type scalping screen which may be inserted into the top rim of the sloping hopper. This will cause any oversized material to be scalped and rolled off the screen to the rear of the machine.

This unit also has a wide range of production capability. The actual rate of production in tons per hour is usually determined by the screening capacity of the screens although, in some cases, the rate may be limited by the capacity of the dual roll crusher.

The 75-TPH plant is typically employed in any of four basic ways depending upon the raw material available and the nature of end products required for construction projects. The four basic setups are as follows:

1. The jaw crusher is used alone to work with quarry rock. Large quantities of material are ordinarily needed for base course, roads, and airfields; the fine particles are desired for binder. This means that all of the crushed material is used together with no screening necessary.

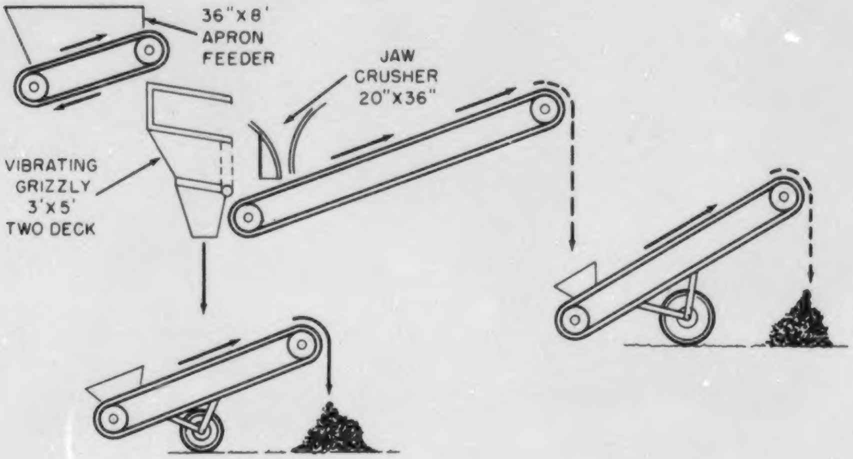
2. The primary and secondary units are used in conjunction with each other to produce graded aggregate from quarry rock. The material is reduced in successive stages and screened to separate material into size ranges required to meet specifications.

3. The primary and secondary units are used together to produce graded aggregate from gravel deposits which are too large in size to be handled by the secondary unit alone.

4. The secondary unit is used alone when the bulk of material in a gravel deposit does not exceed 3 inches in diameter. In this case, a positive means is provided to limit the size of material fed to the unit.

Rarely are two aggregate production operations exactly the same. Each project must be analyzed on the basis of its own particular conditions and requirements. The 75-TPH plant equipment is sufficiently flexible to meet all aggregate requirements of construction battalions. Following are some examples of plant requirements, as dictated by quarry or gravel pit material conditions.

Figure 6-13 illustrates an arrangement used by the primary crusher unit when only coarse ungraded material is desired, or if the product to be hauled or fed directly to a secondary crushing and screening unit. Whether the coarse material is to be screened or not depends on the end product wanted. For base course material, it is often not necessary to screen material from a primary unit–this depends entirely on the specifications that are to be met. In the arrangement shown, material from the primary unit is being stockpiled by conveyor. The

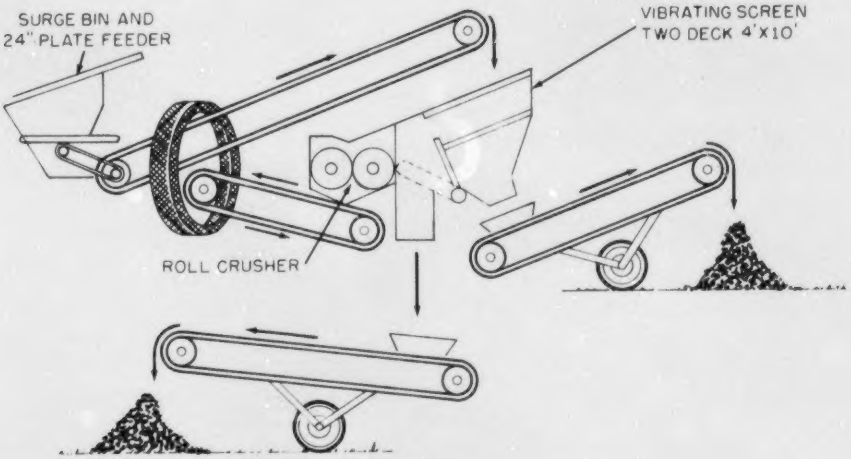

36"x8'
APRON
FEEDER
JAW
CRUSHER
20"x36"
VIBRATING
GRIZZLY
3'x5'
TWO DECK

115.363

Figure 6-13.—Primary unit.

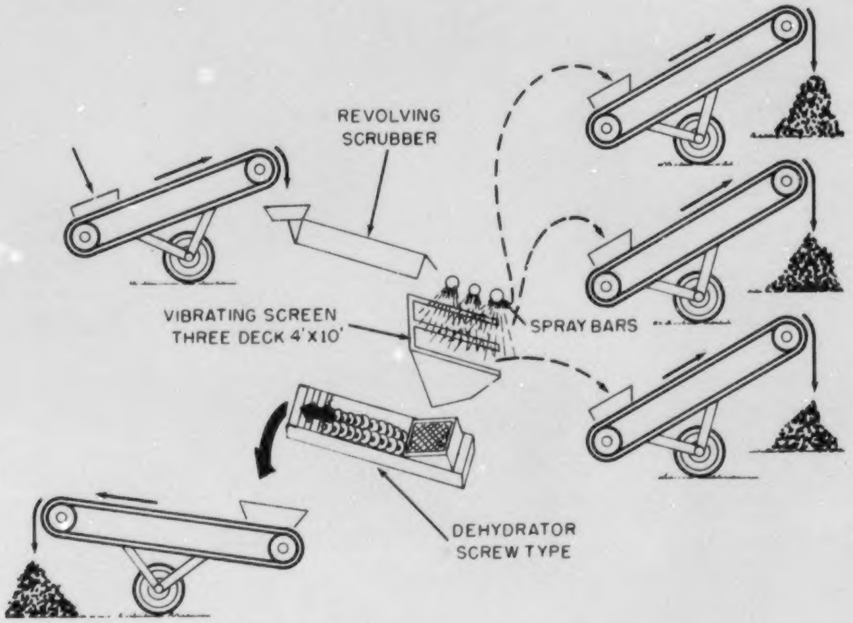
crushed material can also be loaded into dump trucks or other hauling equipment.

Figure 6-14 illustrates an arrangement used by the secondary crusher unit for pit service to produce two sizes of finished product. The arrangement shows conveyors stockpiling material, but the material can be bin loaded or truck loaded. All material feeding this plant should first be dumped onto a grizzly or gate bars over a reciprocating feeder attached to the plant. This keeps all oversized material from entering the plant. All material larger than the roll crusher can handle must be kept out of the roll unit.


SURGE BIN AND
24" PLATE FEEDER
VIBRATING SCREEN
TWO DECK 4'x10'
ROLL CRUSHER

115.364

Figure 6-14.—Secondary unit.


REVOLVING SCRUBBER
VIBRATING SCREEN THREE DECK 4'X10'
SPRAY BARS
DEHYDRATOR SCREW TYPE

115.365

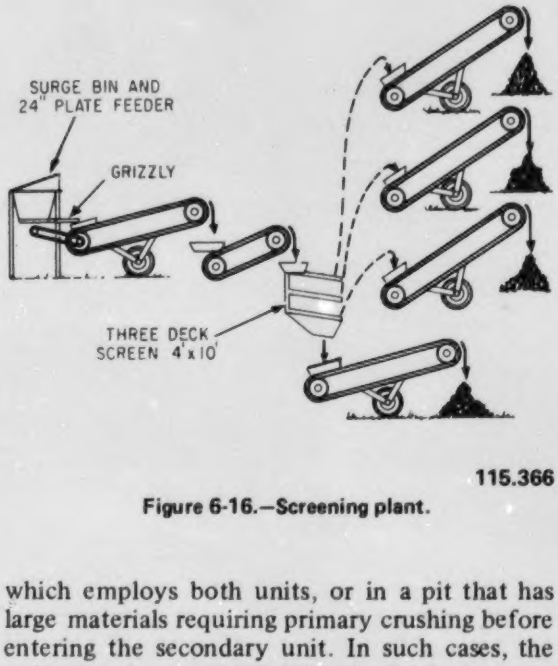
Figure 6-15.—Washing and screening unit.

In many types of construction jobs, it is not necessary to have crushed particles in the finished product; however, it is often necessary that all material be clean and free of objectionable material.

The capacity of the washing and screening plant illustrated in figure 6-15 is based on the percent of sand in the deposit—for example, each single screw washer will handle a certain amount of material. The screen is also a factor to consider when figuring the capacity of this plant. It is necessary to have enough screening area to handle each gradation of material desired.

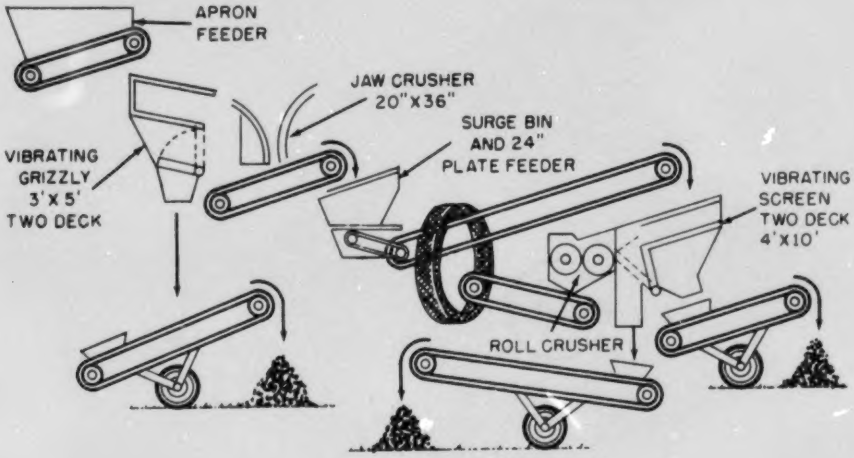
If no crushing or washing is required and the material is only to be separated by screening, the screening plant illustrated in figure 6-16 is normally used. Four sizes of finished product can be produced. If the material must be rinsed in its finished state, the screen may be equipped with spray pipes and nozzles.

The primary and secondary units shown in figure 6-17, may be used either in quarry service, which employs both units, or in a pit that has large materials requiring primary crushing before entering the secondary unit. In such cases, the units can be operated individually in separate locations; however, this depends upon the


SURGE BIN AND 24" PLATE FEEDER
GRIZZLY
THREE DECK SCREEN 4'x10'

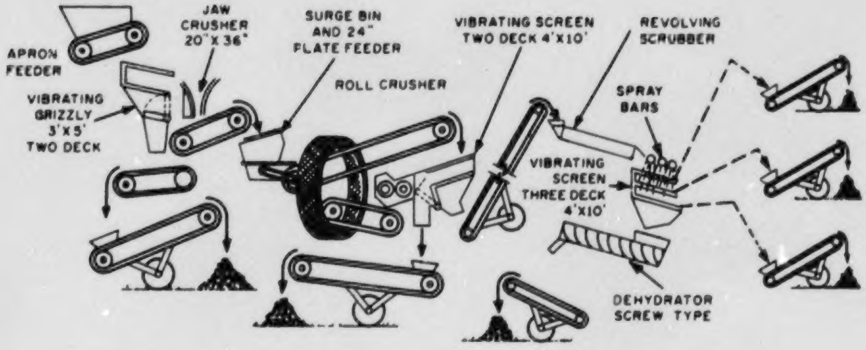
115.366

Figure 6-16.—Screening plant.


APRON FEEDER
JAW CRUSHER 20"X36"
SURGE BIN AND 24" PLATE FEEDER
VIBRATING GRIZZLY 3'X5' TWO DECK
VIBRATING SCREEN TWO DECK 4'X10'
ROLL CRUSHER

115.367

Figure 6-17.—Primary and secondary units.


JAW CRUSHER 20"X36"
SURGE BIN AND 24" PLATE FEEDER
VIBRATING SCREEN TWO DECK 4'X10'
REVOLVING SCRUBBER
APRON FEEDER
ROLL CRUSHER
VIBRATING GRIZZLY 3'X5' TWO DECK
SPRAY BARS
VIBRATING SCREEN THREE DECK 4'X10'
DEHYDRATOR SCREW TYPE

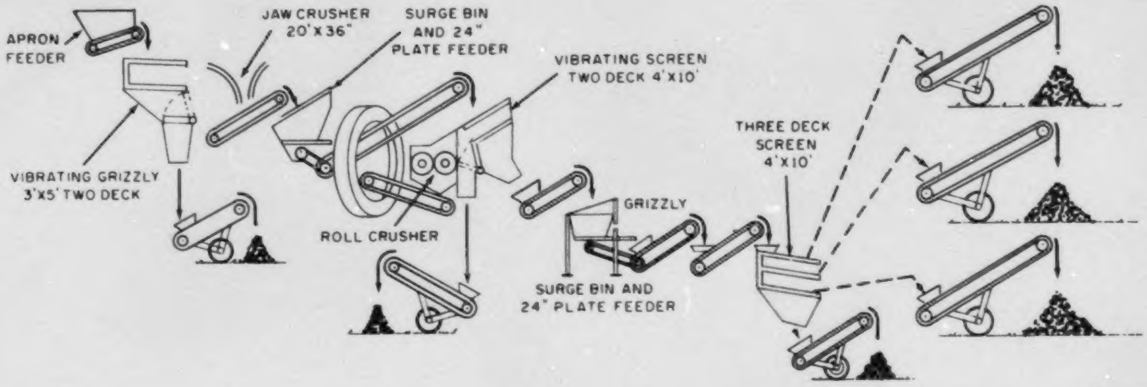
115.368

Figure 6-18.--Primary unit, secondary unit, and washing and screening unit.

product desired and the pit or quarry conditions.

When the primary, secondary, and washing and screening units are arranged as shown in figure 6-18, they can be used in a pit having a large percentage of oversized material. This material requires primary crushing before entering the secondary unit for final crushing, and then on to the washing and screening plant for scrubbing and screening to predetermined sizes. Where all finished products require scrubbing and rinsing, the material from the secondary unit would be directed to the washing and screening unit for processing. The illustration shows two unwashed products from the washing and screening unit.

The arrangement of the primary unit, secondary unit, and screening unit illustrated in figure 6-19 is widely used in quarries and gravel pits containing a large percent of oversized


APRON FEEDER
JAW CRUSHER 20'X36"
SURGE BIN AND 24" PLATE FEEDER
VIBRATING SCREEN TWO DECK 4'X10'
THREE DECK SCREEN 4'X10'
VIBRATING GRIZZLY 3'X5' TWO DECK
GRIZZLY
ROLL CRUSHER
SURGE BIN AND 24" PLATE FEEDER

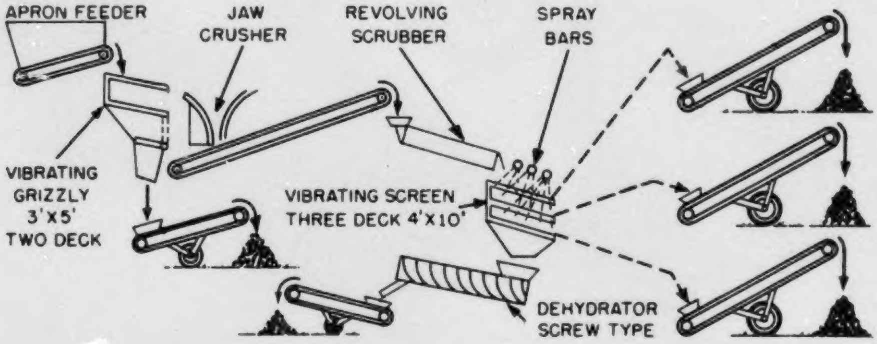
115.369

Figure 6-19.—Primary unit, secondary unit, and screening unit.

material and where more sizes of finished products are desired than can normally be produced from the roll secondary unit. This particular arrangement shows six sizes of finished products being produced. An arrangement like this is sometimes used where there is an excess of sand to be removed—more than the screening area in the secondary unit is capable of handling.

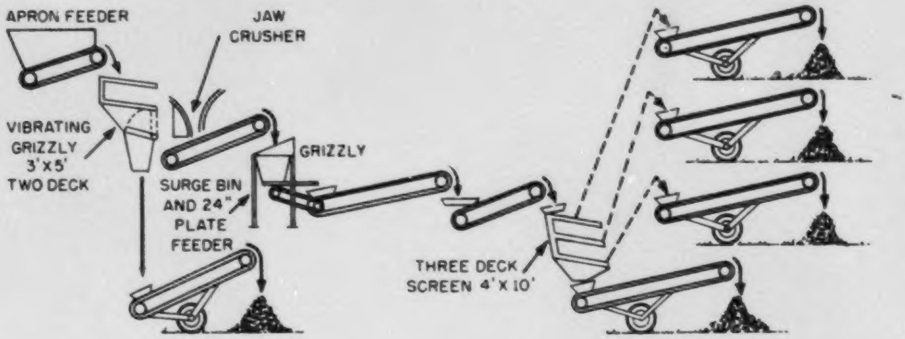
Arranging the primary unit and the washing and screening unit as illustrated in figure 6-20 would be desirable in a quarry or in a pit having large material requiring crushing, and would be used only when material had to be washed and screened. The illustration shows three sizes of finished product and one size of clean, dehydrated sand being produced. Excessive fines can be removed at the primary unit.

Placing the primary unit and screening unit in a combination as shown in figure 6-21 is advantageous when it is necessary to separate material coming from the primary unit. In many operations, large material is required for the base course and, therefore, it is desirable to remove the finer material not needed. This can be accomplished by use of the screening unit. As in


APRON FEEDER
JAW CRUSHER
REVOLVING SCRUBBER
SPRAY BARS
VIBRATING GRIZZLY 3'X5' TWO DECK
VIBRATING SCREEN THREE DECK 4'X10'
DEHYDRATOR SCREW TYPE

115.370

Figure 6-20.—Primary unit, and washing and screening unit.


APRON FEEDER
JAW CRUSHER
VIBRATING GRIZZLY 3'x5' TWO DECK
GRIZZLY
SURGE BIN AND 24" PLATE FEEDER
THREE DECK SCREEN 4'x10'

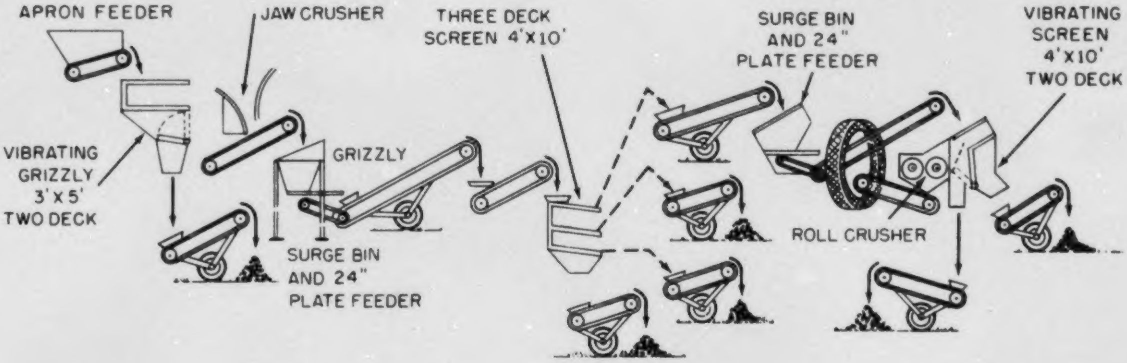
115.371

Figure 6-21.—Primary and screening unit.

other screening units, the number of decks or screens are governed by the amount of tons to be produced along with the openings in the screens.

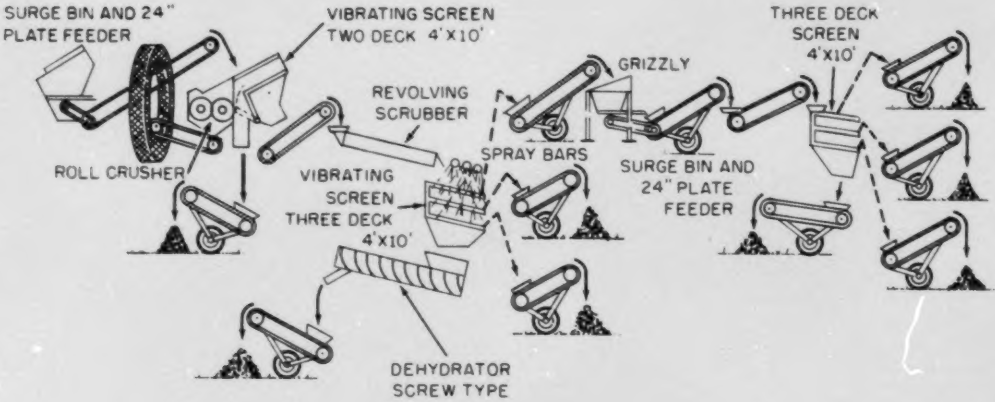
Arrangement of the primary unit, screening unit, and secondary unit for high speed production of accurately sized material as shown in figure 6-22 would be desirable when a great volume of work is to be accomplished. This is an ideal setup for quarry service when producing road chips for seal coatings. It is also used in gravel pit operations for the same purposes. The screening unit separates all material according to size, allowing only the oversized material to pass on to the secondary unit for final reduction. This generally increases the capacity of the plant.

When more than three sizes of washed finished product and sand are required, the secondary unit, washing and screening unit, and screening unit are arranged in the manner illustrated in figure 6-23. The oversize material from the top deck of the washing and screening unit is conveyed to the screening unit for further separation. In this arrangement, five sizes of washed material, one size of clean sand, and one


APRON FEEDER
JAW CRUSHER
THREE DECK SCREEN 4'x10'
SURGE BIN AND 24" PLATE FEEDER
VIBRATING SCREEN 4'x10' TWO DECK
VIBRATING GRIZZLY 3'x5' TWO DECK
GRIZZLY
ROLL CRUSHER
SURGE BIN AND 24" PLATE FEEDER

115.372

Figure 6-22.—Primary unit and secondary unit.


SURGE BIN AND 24"
PLATE FEEDER
VIBRATING SCREEN
TWO DECK 4'X10'
THREE DECK
SCREEN
4'X10'
GRIZZLY
REVOLVING
SCRUBBER
ROLL CRUSHER
SPRAY BARS
VIBRATING
SCREEN
THREE DECK
4'X10'
SURGE BIN AND
24" PLATE
FEEDER
DEHYDRATOR
SCREW TYPE

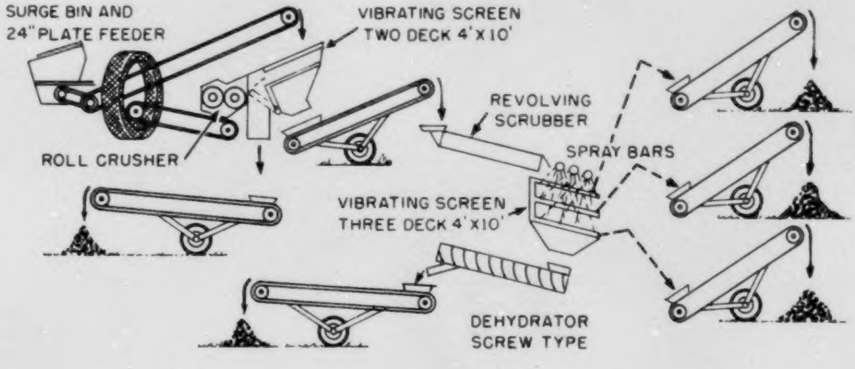
115.373

Figure 6-23.–Secondary unit, washing and screening unit, and screening unit.

size of unwashed material can be produced at the same time. Ordinarily, all the material from the roll secondary unit would go to the washing and screening unit, to produce all clean washed materials.

When material from a secondary unit must be scrubbed and rinsed to produce a clean dehydrated sand, the arrangement of the roll secondary unit and washing and screening unit as shown in figure 6-24 is generally used. Normally, all material from the secondary unit is directed to the washing and screening unit, but unwashed products can be taken from the secondary unit if necessary.

A roll secondary unit usually produces one or two sizes of finished products. If additional separation is necessary, the screening unit must be used. Also, in some pits the percentage of fines is so great that the bottom deck of the screen in the secondary unit is too small in area to properly screen the material. It is then necessary that the bottom deck be removed and


SURGE BIN AND
24" PLATE FEEDER
VIBRATING SCREEN
TWO DECK 4'X10'
REVOLVING
SCRUBBER
ROLL CRUSHER
SPRAY BARS
VIBRATING SCREEN
THREE DECK 4'X10'
DEHYDRATOR
SCREW TYPE

115.374

Figure 6-24.–Roll secondary unit and washing and screening unit.

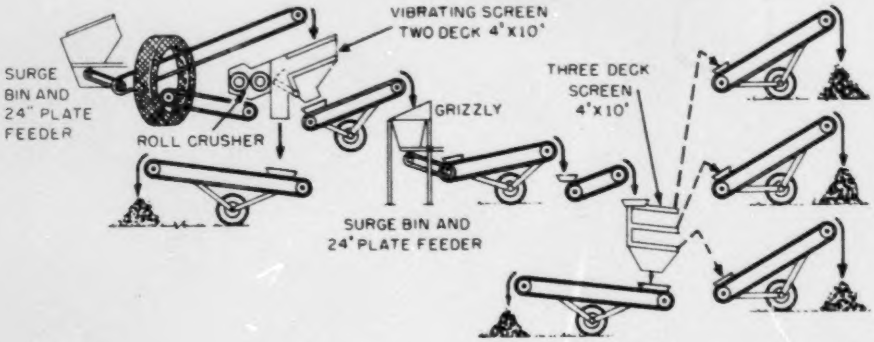
200

all material from the secondary unit be directed to a larger screen for separation. With the arrangement of the roll secondary and screening unit as illustrated in figure 6-25, five sizes of finished product can be produced at the same time.

When no crushing is required, the washing and screening unit and the screening unit may be set up as shown in figure 6-26 for use in a sand and gravel pit. These units are capable of producing six sizes of washed finished products and one size of clean dehydrated sand. This arrangement is particularly advantageous where a considerable amount of undesirable material is in the deposit. Because the scrubbing and abrasive action of the revolving scrubber tends to loosen such material, the wash water floats the material over the weirs of the single screw washed-dehydrator-classifier. In this arrangement, capacity is governed by the percentage of sand in the deposit, the total tonnage fed to the unit, and the gallons of water required per minute to thoroughly clean the material.

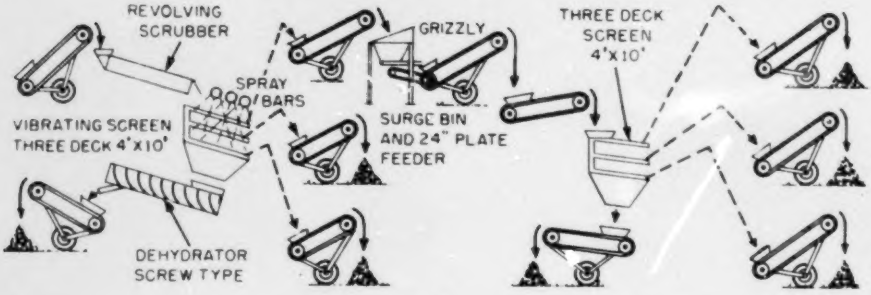
MAINTAINING QUARRY EQUIPMENT

The entire quarry and rock production operation depends on proper and adequate


VIBRATING SCREEN
TWO DECK 4'x10'
SURGE BIN AND 24" PLATE FEEDER
ROLL CRUSHER
GRIZZLY
THREE DECK SCREEN 4'x10'
SURGE BIN AND 24' PLATE FEEDER

115.375

Figure 6-25.—Roll secondary and screening unit.


REVOLVING SCRUBBER
GRIZZLY
THREE DECK SCREEN 4'x10'
SPRAY BARS
VIBRATING SCREEN THREE DECK 4'x10'
SURGE BIN AND 24" PLATE FEEDER
DEHYDRATOR SCREW TYPE

115.376

Figure 6-26.—Washing and screening unit and screening unit.

maintenance of equipment. A regulated program of maintenance, including step-by-step procedures, is recommended for each piece of equipment.

In contrast to other types of construction equipment, procurement of repair parts and new units for crushing and screening equipment requires a much greater lead time. Therefore, without these parts and units, production either slows down or stops altogether.

As the supervisor in charge of crushing and screening operations, see that preventive maintenance procedures are performed by the operators and maintenance mechanics to insure continuous operation of the equipment.

CAUTION: Be sure the main power sources remains "OFF" while personnel are working on electrical equipment.

Often scheduled maintenance is put off to a later date because of production demands. While this may satisfy the immediate production demands of the unit, it is not good for the equipment and creates a lax attitude toward scheduled maintenance. A precedent is set that leads to putting maintenance second to production. When this happens, it will not be long before production rates decline because of equipment breakdowns.

Frequent inspections should be made during operation to see that the equipment is not being abused, that the units are level and cribbed, that calibrations are correct, and that proper shutdown procedures are followed.

BLASTING OPERATIONS

Blasting operations are usually necessary when working a quarry that contains materials that cannot be removed with construction equipment, such as front-end loaders, power shovels, bulldozers, and hauling equipment. Should this be the case, blasting will come under the direct supervision and control of a qualified Blaster who carries the NEC EO-5708.

All other quarry personnel assigned will follow written and oral instructions, carryout assigned duties, and observe all safety precautions.

The fewer personnel handling explosives, the fewer will be the risks of accident. This means one or two Blaster's have a definite assignment of the several tasks involved in loading and firing a blast. These include carrying explosives and detonators, opening cases, priming, loading, stemming, connecting blasting circuits, and firing so that the entire quarry crew know exactly what the Blaster's duties are. With such a system everything will be done in a precise and orderly manner with no haphazard assumption of the various tasks to be performed. Therefore, those of you not directly concerned with the work will keep away from it.

Greater detail on blasting safety is given in appendix II of this training manual.

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CHAPTER 7

WELL DRILLING

Napoleon said, "An army fights on its stomach." Food is an important item with everyone in the Navy. However, water is just as important to a fighting unit as food and if uncontaminated surface supplies are not readily available, wells must be drilled.

After our forces landed on Guadalcanal and Okinawa during World War II, and more recently in Vietnam, it was necessary to develop additional sources of water supply. You are right–it was another job for the SEABEES, and they did the job. They drilled wells, and in some cases are still drilling wells, that have produced thousands of gallons of water.

WATER SOURCES

Drilling water wells is an art for which there are no hard and fast rules, and oftentimes a good deal of common sense and improvisation is required on the part of the driller. In addition, a driller should have a general knowledge of our ground water resources and the physical structure of the earth's crust. Problems often arise in drilling and the driller should be able to visualize what is happening in the bottom of the hole. An awareness of the conditions under which ground water occurs and of geologic conditions is a shortcut to the solution of some drilling problems that would otherwise take a good deal of time and experience to attain through the trial-and-error method.

Contrary to popular belief, water recovered from beneath the ground accounts for a much larger percentage of our water supply than that from natural lakes or manmade reservoirs.

The source of all fresh water upon and in the land areas of the earth is the oceans. Precipitation in the form of rain, hail, sleet, or snow recharges lakes, streams, and underground water. Part of the precipitation over land areas soaks into the ground and under the influence of gravity moves downward until it becomes part of the saturated zone. Only water in the saturated zone is properly referred to as ground water. It is in this zone that wells are developed.

Above the saturated zone is another zone, called the zone of aeration. This zone is divided into three belts: Belt of soil water or plant root zone, intermediate belt, and capillary fringe. Neither of the latter zones is capable of producing water in usable quantities since the pores or open spaces between individual particles are not all filled with water. Water in the zone of aeration is called subsurface water and should not be confused with ground water contained in the saturated zone where all the pores are filled with water.

The volume of water contained in the saturated zone is the total volume of the openings in rocks or between the individual grains of sand or gravel and is referred to as the particular material's porosity.

The physical characteristics of the zone of saturation may vary widely depending upon the geologic formations of earth layers; i.e., sand, gravel, clay, rock, or a combination of these. This zone may also vary in depth from a few feet to many hundreds. Water may be found in one continuous body or in alternating layers of clay and sand within the saturated zone. While clay may hold a relatively high volume of water, the openings between the individual particles are so small as to prevent the flow of water. Clay is then said to be impermeable. Confined between two layers of clay may be a layer of sand which is both porous (holds water) and is permeable (allows the water to flow).

A porous and permeable formation that will yield water in usable quantities is called an aquifer. If an aquifer is not confined by an impermeable layer above it, the aquifer is said to be under water table conditions and is subjected to atmospheric pressure. If an aquifer is confined both above and below and the recharge area or source of water is higher than the point where a well is to be located, the water will be under greater than atmospheric pressure and will rise to some point above the water table. If the pressure is sufficient the well may be free flowing. An aquifer under this condition is called an artesian.

Formations of sedimentary, igneous, and metamorphic rocks are potential sources of water. Sedimentary rocks are among the most common aquifers. They are formed by the accumulation of sediments that have been deposited by water, wind, or ice. Limestone is an example of a sedimentary rock, having been formed by the accumulation of chemical compounds and minerals that settle together out of water. Water percolating through cracks and joints in a dense limestone deposit results in underground streams and lakes. Throughout thick, nearly horizontal layers of interbedded shale, sandstone, and limestone are huge reservoirs of ground water.

Igneous and metamorphic rocks should be viewed together as a group of hard, dense rocks. Unless highly fractured and occurring close to the earth's surface, they produce far less water than sedimentary rocks. The recovery of water from solid rock depends on the existence of many cracks, fissures, or crevices in the rock. Extremely fine deposits of sedimentary materials usually produce little water. Although highly porous, they are relatively impermeable.

Topographical features created by water action offer an excellent chance for the recovery of ground water at relatively shallow depths. Such features include: alluvial valleys which are rather extensive in area and are the sites of ancient rivers or the flood plains of active rivers; alluvial fans which are an accumulation of sediments at the base of mountains, deposited where drainage streams fan out; alluvial basins which are essentially structural troughs created by a rim of mountains; and glacial outwash.

GROUND WATER EXPLORATION

Where extensive ground water exploration has not occurred, maps, official documents, unofficial documents, and native experience must be utilized to obtain a fairly reliable indication as to a particular area's ground water resource. The information available, in most cases, gives an idea as to the geological conditions, such as terrain and type of material, approximate depth to an aquifer or series of aquifers, quantities of water that may be expected during different seasons of the year, average depth to the water table, and drilling problems that may be encountered.

Access to maps and publications is usually through hydrographic offices either on a state or national level, offices of the United States Coast and Geodetic Survey or its equivalent in other countries, geological or university archives, battalion engineering offices, or native drillers.

When little or nothing is known of the water resource in a particular area, the most valuable clues may come from an inspection of the outcroppings of rock formations. It may be necessary to verify one's conclusions by exploratory drilling, which is the surest way to establish the existence of water bearing formations.

Exploratory drilling is usually initiated as part of the ground water study of an area, before construction of one or more wells at a particular site.

WELLS

Wells are classified into five types, according to their method of construction. These are dug, bored, jetted, driven, and drilled wells. Each type of well has certain advantages and limitations; and the type of well to be developed will depend on ease of construction, storage, capacity, limitations as to formations it can penetrate, and ease of safeguarding it against pollution.

A DUG well is one in which the excavation is made by the use of picks, shovels, spades, or digging equipment such as sand buckets or clamshell buckets.

A BORED well is one in which the excavation is made by the use of hand or power augers.

A JETTED well is one in which the excavation is made by the use of a high-velocity jet of water.

A DRIVEN well is one which is constructed by driving a pointed screen, referred to as a drive point, into the ground. Casings or lengths of pipes are attached to the drive point as it is being driven into the ground.

Dug, bored, jetted, and driven wells are relatively shallow. Generally, they are less than 50 feet deep and may be constructed with handtools. DRILLED wells may be as deep as 1500 feet and are constructed with portable well-drilling machines, either rotary or percussion.

ROTARY AND PERCUSSION DRILLING

The method of drilling for water is referred to as rotary or percussion, depending on the kind of drilling machine or rig used. Ordinarily, the method used is decided by whether the available machine is rotary or percussion. Some machines can drill by either method. They work to advantage in situations that call for both rotary and percussion drilling.

Under certain drilling situations, neither method will have the advantage over the other. For example, both machines can use any available fresh water supply or even salt water in an emergency. In other drilling situations, one method holds the advantage over the other. Rotary drilling is considered faster and more economical when a test well is to be drilled through soil formations that are free of boulders. But the rotary machine does not drill satisfactorily in extremely absorbent underground formations. The percussion method (called spudding) is preferred for drilling moderate depths in consolidated formations because less water is used and it is easier to get representative samples of the formations being drilled. On the other hand, the spudding rig is unsatisfactory for drilling deep small-diameter holes in soft, loose soils, such as dune sand and river gravels.

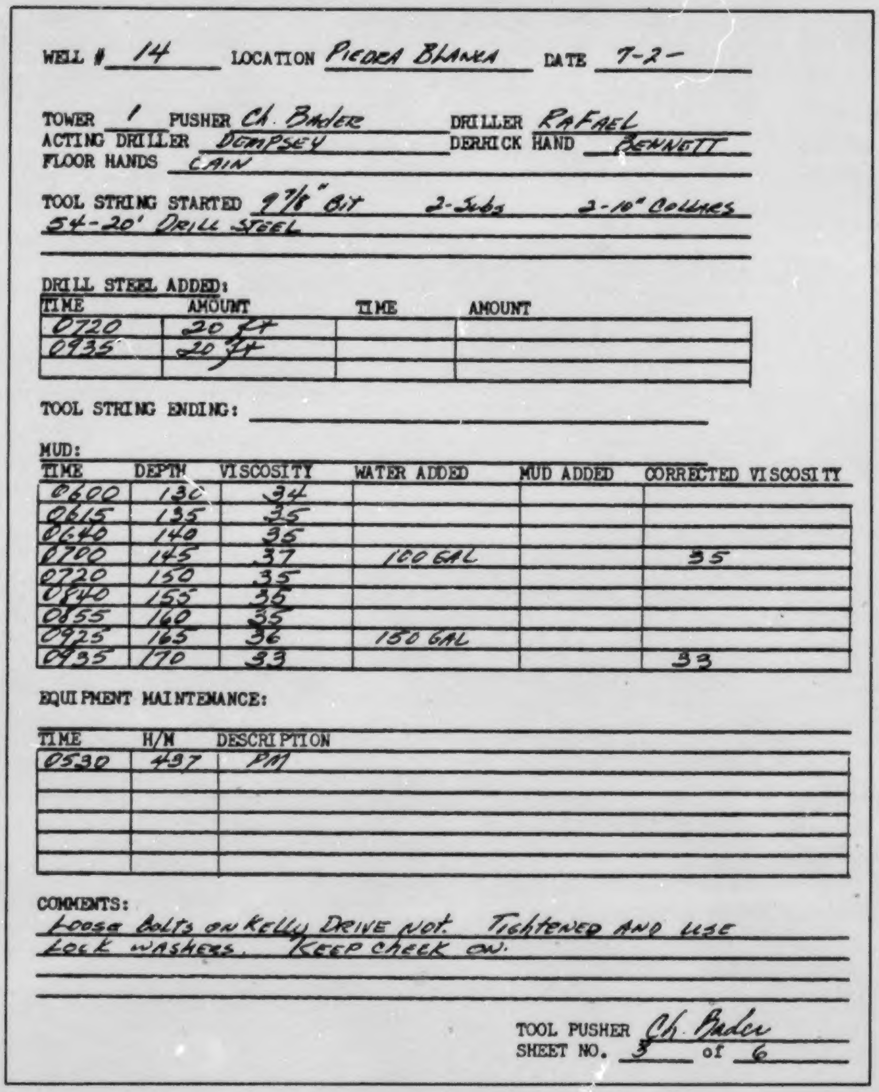
Regardless of whether the drilling method is rotary or percussion, the objectives of drilling are to (1) identify and locate the site of each test hole, (2) maintain a log of formations penetrated and representative samples obtained, and (3) determine the depth to each water level and obtain samples of water from aquifers.

Essentially, the drillers log (fig. 7-1) should be an accurate record of the depth, changes in formations with a description of the samples taken every 5 feet or at every formation change, and a description of the drilling action which is a valuable clue to a change in formation. For example, with the rotary method, drilling action in clay or shale is smooth. Chattering of the bit is an indication of sand or gravel; smooth drilling, but rapid penetration, indicates fine sand.

Another useful log is the drilling time log or well log (fig. 7-2). It includes all the information in the drillers log as well as information of the time it took to drill each foot. As drilling speed is largely determined by the composition of the formations, information from the well log may be used in graph form to reveal the top, bottom, and thickness of each formation. Clues to the composition of each formation are provided by this log and verified by the samples obtained.

ROTARY DRILLING

In using a hand drill to bore a hole, you press the cutting tool or bit into the material to be bored. The material is cut as you turn the bit by means of the drill handle. During the drilling process, chips of cut material are carried to the top of the hole by the spiral flutes of the bit. A rotary drilling machine operates on the same principle, except for the method of raising the cut material. This material is washed to surface by a fluid substance instead of being carried by the bit itself. The bit of a rotary drilling machine



WELL # 14 LOCATION PIEDRA BLANCA DATE 7-2-

TOWER 1 PUSHER Ch. Bader DRILLER RAFAEL
ACTING DRILLER DEMPSEY DERRICK HAND BENNETT
FLOOR HANDS CAIN

TOOL STRING STARTED 9 7/8" BIT 2-SUBS 2-10" COLLARS
54-20' DRILL STEEL

DRILL STEEL ADDED:

TIME	AMOUNT	TIME	AMOUNT
0720	20 ft		
0935	20 ft		

TOOL STRING ENDING:

MUD:

TIME	DEPTH	VISCOSITY	WATER ADDED	MUD ADDED	CORRECTED VISCOSITY
0600	130	34			
0615	135	35			
0640	140	35			
0700	145	37	100 GAL		35
0720	150	35			
0840	155	35			
0855	160	35			
0925	165	36	150 GAL		
0935	170	33			33

EQUIPMENT MAINTENANCE:

TIME	H/M	DESCRIPTION
0530	497	PM

COMMENTS:
LOOSE BOLTS ON KELLY DRIVE NOT. TIGHTENED AND USE LOCK WASHERS. KEEP CHEEK ON.

TOOL PUSHER Ch. Bader
SHEET NO. 3 of 6

143.226

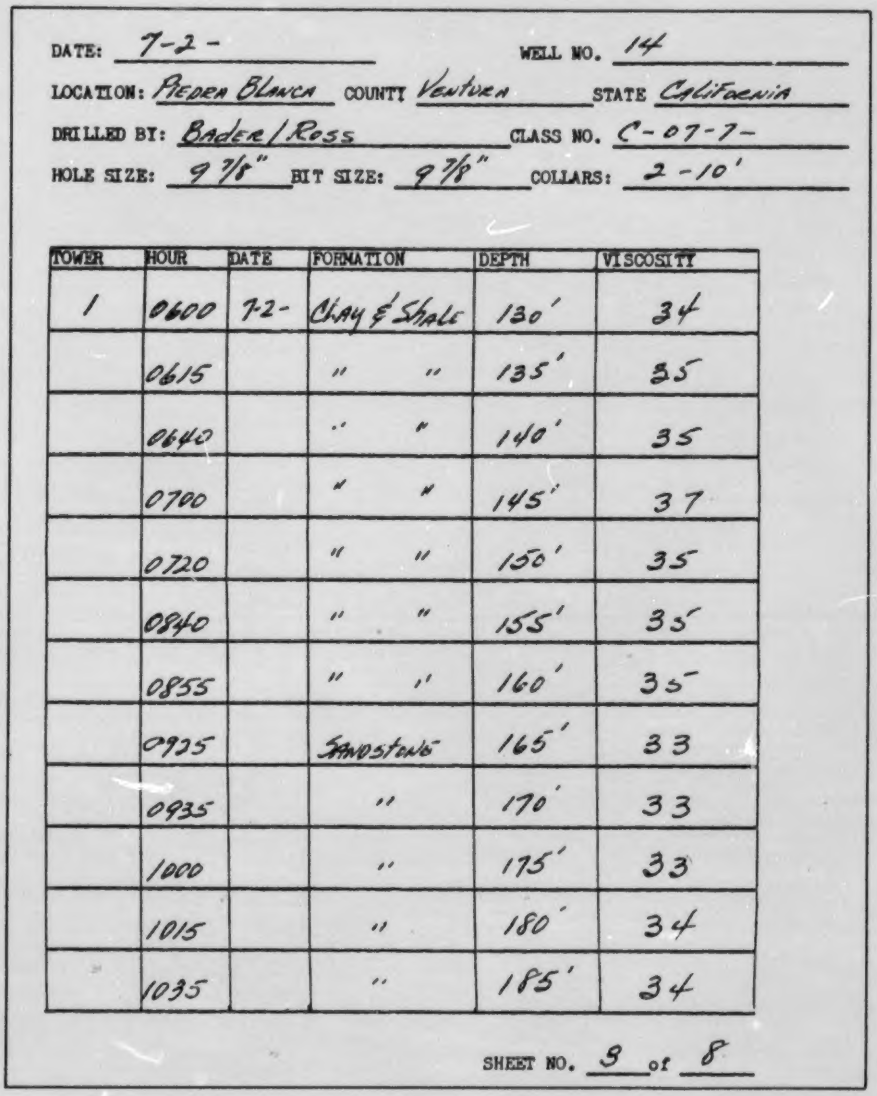
Figure 7-1.—Drillers log.

is attached to the lower end of the drill pipe (fig. 7-3).

Operating Principles

The basic parts of a rotary drilling rig are the derrick and hoist, kelly, turntable, drill, pipe, bit, and pump. These and other parts are shown in figure 7-3.

The drill pipe comes in lengths that are joined together as the depth of the well increases. The top joint of the drill pipe is connected to the kelly, a splined hollow shaft which passes up through the turntable and kelly



DATE: 7-2-
WELL NO. 14
LOCATION: Piedra Blanca COUNTY Ventura STATE California
DRILLED BY: Bader/Ross CLASS NO. C-07-7-
HOLE SIZE: 9 7/8" BIT SIZE: 9 7/8" COLLARS: 2-10'

TOWER	HOUR	DATE	FORMATION	DEPTH	VISCOSITY
1	0600	7-2-	Clay & Shale	130'	34
	0615		" "	135'	35
	0640		" "	140'	35
	0700		" "	145'	37
	0720		" "	150'	35
	0840		" "	155'	35
	0855		" "	160'	35
	0925		Sandstone	165'	33
	0935		"	170'	33
	1000		"	175'	33
	1015		"	180'	34
	1035		"	185'	34

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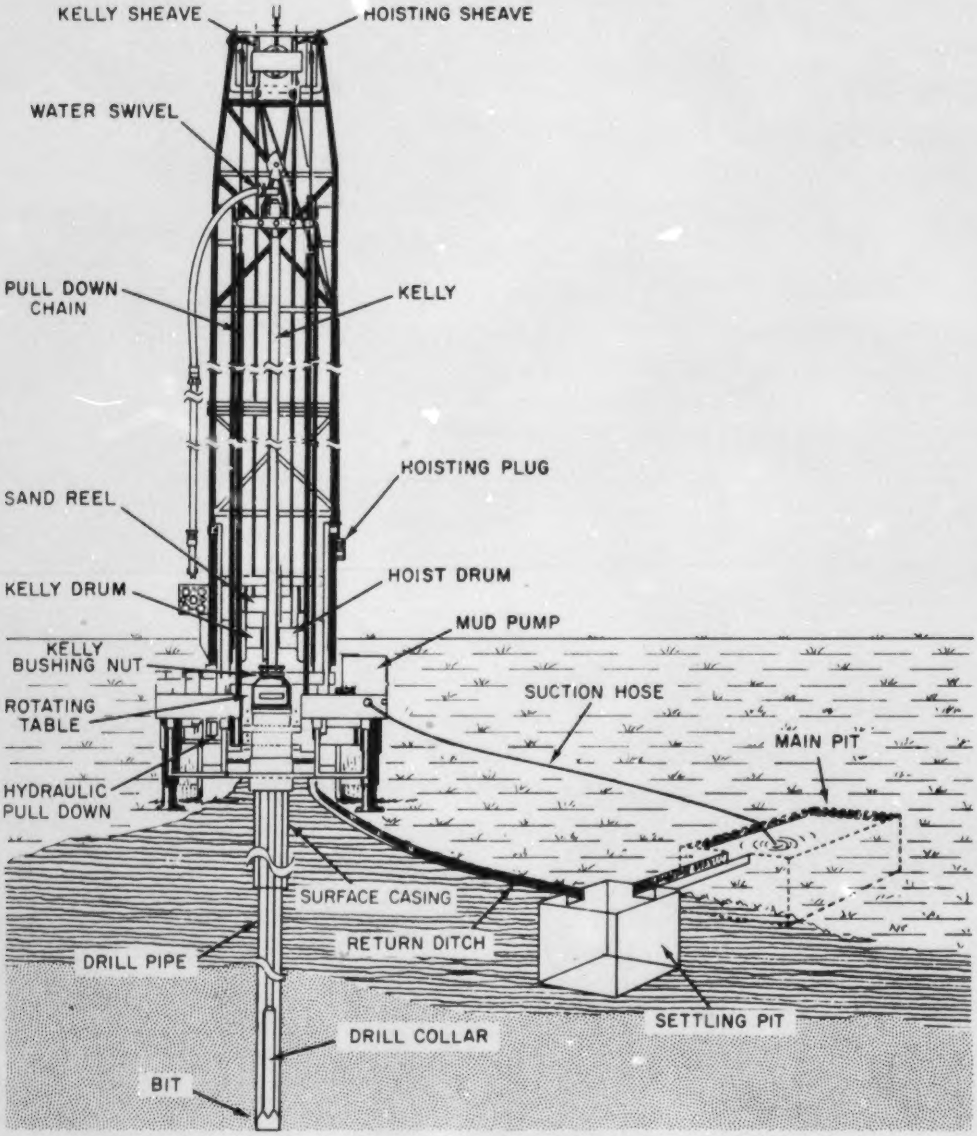
143.227

Figure 7-2.—Well log.

bushing. This bushing is grooved to fit the splines on the kelly. When rotated by the turntable, the kelly is free to move up and down. The pump forces a mixture of clay and water through the kelly and drill pipe.

A water swivel, suspended from above, is attached to the top of the kelly. It allows the kelly, drill pipe, and bit to rotate with the driving mechanism. The swivel and kelly are raised and lowered by a cable that runs from the swivel over a sheave at the top of the derrick down to the kelly drum. The kelly drum brakes and cable control the pressure and rate of feed to the bit by holding off or applying the weight of the drill pipe.


KELLY SHEAVE
HOISTING SHEAVE
WATER SWIVEL
PULL DOWN CHAIN
KELLY
HOISTING PLUG
SAND REEL
KELLY DRUM
HOIST DRUM
MUD PUMP
KELLY BUSHING NUT
ROTATING TABLE
SUCTION HOSE
MAIN PIT
HYDRAULIC PULL DOWN
SURFACE CASING
RETURN DITCH
DRILL PIPE
SETTLING PIT
DRILL COLLAR
BIT

143.295

Figure 7-3.—Rotary method of drilling.

The accessories of a rotary drilling rig include the hoisting plug, slips, drill collar, kelly sub, and casing. The hoisting plug (fig. 7-4) is the connecting link between the hoisting line and the drill pipe. It swivels so that the drill pipe is free to turn while being hoisted. The slips (fig. 7-5) are used to hold the drill pipe when it is being moved in or out of the hole while a joint is removed or added. The slips are circular wedges made in two or four pieces and fastened

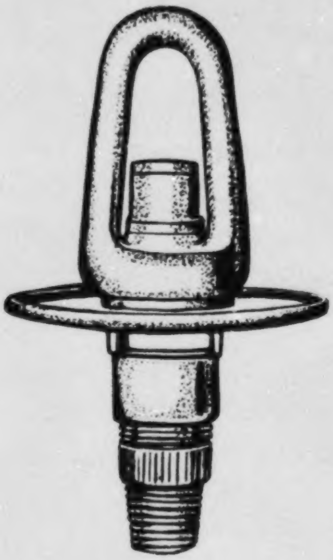


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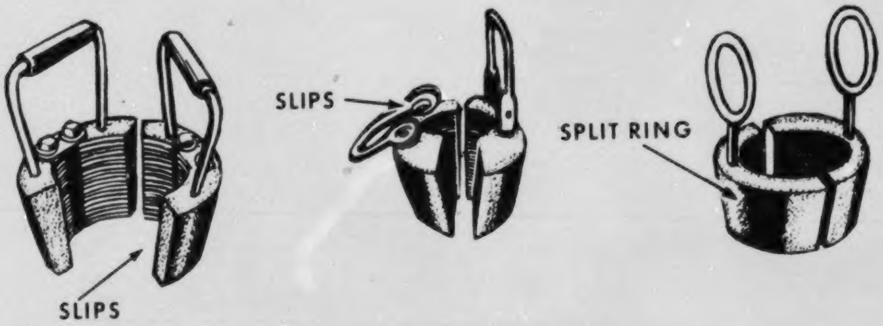
Figure 7-4.—Hoisting plug.

together in sets or pairs. Teeth on the inside surface of each slip grip the outside surface of the drill pipe. The slips are also tapered so that when set around the drill pipe and pulled into the turntable, they grip the drill pipe securely. The drill collar (fig. 7-3) joins the bit and drill pipe and helps stabilize the bit and keep the hole uniform and straight. This collar is 10 feet long and has a diameter larger than that of the drill pipe, yet small enough to clear the wall of the hole. The kelly sub (or wear sub) connects the kelly to the drill pipe. When it becomes worn, it can be changed instead of the entire kelly.

In areas where surface formations are soft or sandy, it is necessary to set the casing to keep the walls of the hole from caving and to prevent the hole from being enlarged by the washing action of the circulating fluid. Sometimes, the hole is reamed or enlarged in order to set the casing on a firm foundation. To run the casing, a sub is attached to the hoisting plug and threaded into a length of the casing. Some casing is not threaded; therefore, it must be welded together. It can be washed and cooled down by the mixing hose from the mud pump. It is then run into the hole in the same manner as the drill pipe. If the hole has caved so the casing will not go down, attach the swivel to the casing with a sub and circulate fluid through the casing. This is called washing down and is sometimes used to wash the casing to the bottom of a caving hole.

The kelly and drill pipe are hollow to allow a fluid mixture of clay and water to be pumped through them to the bit. The fluid circulates through the drill pipe and out through the bit, where it sweeps under the bit, picks up the material loosened by it, and carries the material to the surface through the space between the drill pipe and walls of the well. Fluid from the well overflows into a ditch and passes into a settling pit, where the cuttings settle. The fluid,



143.43

Figure 7-5.—Slips.

free from coarse material and containing only fine-grained clay in suspension, flows into another pit and is picked up by the pump for recirculation in the well.

Enough mud-laden fluid (drilling mud) must be circulated to cool and clean the cutting tool properly and to rise in the hole fast enough to carry the cuttings with it. The fluid's weight and viscosity, aided by the plastering action of the fluid spiraling against the wall of the well, prevent the wall from caving. The consistency of the mud must permit the cuttings to be held in suspension in the hole, yet permit them to settle out in the surface pits. Although some local clays will mix to an acceptable consistency, many do not. A commercially prepared clay, such as Bentonite, must be added to improve the mud's consistency in these cases. As a general rule, one bag of Bentonite clay is added for every 300 gallons of water used in the mixture.

Operating the Rig

Since operating the rotary drilling machine is not too complicated, successful drilling will depend more on the efficiency and experience of the operating crew than knowledge of mechanics and operating principles. Normally, the rig is operated by a crew of four–tool pusher, driller, derrick hand, and floor hand. The tool pusher is responsible for outlining the overall drilling program and seeing that it is carried out. The driller carries out the drilling orders and operates the rig. The derrick hand works in the mast and performs tasks, such as racking the steel pipe, screwing the hoisting plug, and handling the drill pipe or casing. The floor hand makes and breaks the pipe or casing connections and cares for all worktools and equipment on the floor of the rig.

All crewmembers should wear protective clothing or equipment, such as hard hats, gloves, safety shoes, and safety belts. In wearing the hard hat, the derrick man or other crewmember working overhead should secure it to himself to keep the hat from dropping on personnel below. Also while working in the mast, crewmembers should securely attach their tools to the safety belt by means of lines. Before ascending, they should clean their shoes of all mud and inspect footholds for grease. Nobody should wear loose or flapping clothes. Gloves should be worn for protection in handling cable or burred metal. Safety shoes with reinforced tops will protect toes from being crushed.

In rotary drilling, details of setting up the rig will vary–depending on the rig used. Some machines are skid-mounted, others are trailer-mounted, and still others are truck-mounted. In any case, it will be necessary to have the rig level before operations begin. If the rig is on skids, use cribbing and jacks to level the unit. If the unit is truck- or trailer-mounted, level it by digging holes for the wheels on the highest side or by blocking up the low wheels, or both. Keeping your rig level will help keep the hole straight during drilling operation.

While the rig is being leveled, part of the crew can dig the slush (main) pit. A fluid return ditch should be dug from the drilled hole to the settling pit and from the settling pit to the main pit. The ditches enter and leave the settling pit (fig. 7-3) in such a way that the flow of fluid is reversed and causes the cuttings to settle, thus keeping them from flowing to the main pit. The pits are sealed with drilling mud and water added. Once the mud pits are full of water, drilling mud can be added and mixed to the right viscosity with the mixing hose. The suction-hose screen is then placed in the main pit at the opposite end of the return ditch. The suction hose is submerged at all times but does not lie on the bottom.

Keep the circulating fluid as clean and free from abrasives as possible to protect the pump parts. The settling pit should be cleaned frequently so that cuttings will not be placed in circulation. The pit may be cleaned during drilling or when the machine is stopped for a drill pipe change.

A water supply is essential in drilling wells. There is no set rule for determining the amount of water required to drill any one hole. In some cases, where the formations are compact, 3 to 4 gallons of water per foot of hole drilled is sufficient. In other cases, where formations are loose and extremely porous, a large supply of water is required. For ordinary purposes, 750 to 1000 gallons of water per 8-hour shift is needed. Skid-mounted and canvas water tanks are usually a part of the drilling outfit.

Different techniques are often required in drilling holes, even those spaced only a short distance apart in the same soil formation. The driller must be able to select the best bit for penetrating a particular formation. Some rotary drilling bits are shown in figure 7-6. The ROLLER- or CONE-TYPE rock bit is used to penetrate moderately hard to hard formations; the FISHTAIL, 3-WAY, or PILOT bit to penetrate soft formations and overburden material.

Before starting to drill with your rotary rig, it is a good idea to consult its manufacturer's manual. Make sure the drilling table or platform is clean, dry as possible, and free of loose tools. Doing so will help prevent personal injury and loss of tools down the borehole. Also for safety's sake, see that the sheave guards remain in place over moving gears and chain drives while the rig is operating. The good driller learns from experience why a well is dug in a certain way, and visualizes conditions at the bottom of the hole. There are no set rules to follow in adjusting speeds of rotation and bit pressures.

In general, you proceed to set up the portable rig as follows: Move the rig into position on the selected site. Use the hydraulic outriggers to level the rig and take its weight off the axles. Next, raise the mast and lock it into place. Now check to see that the rig is slightly higher in the rear to allow for settling during the drilling operation.

You continue by doing the following: Run the kelly through the turntable and thread the pilot bit to the kelly. Place the turntable transmission in the proper gear for the soil formation being drilled. Engage the turntable clutch and release the kelly brake slowly to lower the bit into the ground. After the bit has spudded in to a depth of six to eight inches, engage the mud pump and lower the kelly. Proceed to drill to the depth of the kelly. At this time, shut off the mud pump and stop the turntable. Next, raise the kelly until the pilot bit reaches the surface. Remove the pilot bit and lift the kelly clear of the turntable. Move the turntable from its position over the hole. Raise, then lower, a surface casing into the hole, using the hoisting drum. The surface casing keeps the well from caving in from the surface. Once again, position the turntable over the hole. Next raise, then lower, a length of drill pipe into the hole through the turntable, using the hoisting line. The slips will hold the drill pipe in place in the turntable. Follow up by lowering the kelly and attaching it to the drill pipe. To keep these

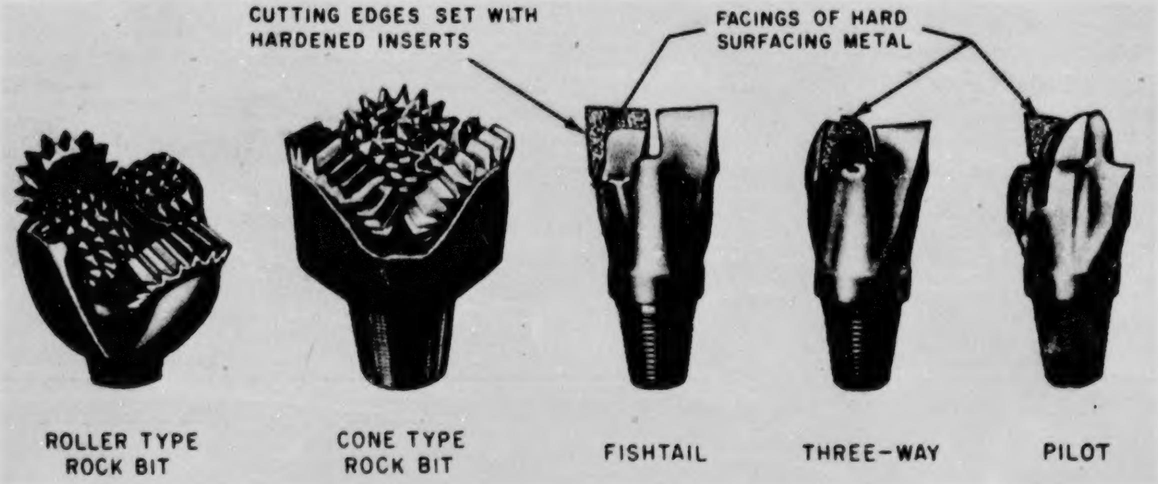

CUTTING EDGES SET WITH HARDENED INSERTS
FACINGS OF HARD SURFACING METAL
ROLLER TYPE ROCK BIT
CONE TYPE ROCK BIT
FISHTAIL
THREE-WAY
PILOT
143.44

Figure 7-6.–Types of bits.

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parts from seizing, apply wicking on the kelly coupling. Using the kelly drum, raise the kelly and attached drill pipe just enough to enable the slips to be removed. Lower the kelly and drill pipe so the kelly bushing nut slips into the turntable. Engage the turntable and start the mud pump. In doing so, you lower the kelly to drill again. Continue drilling to the depth of the kelly. Then shut off the mud pump and stop the turntable. Raise the kelly until a joint clears the turntable. The slips hold the drill pipe in place until the breakout thongs are attached to the kelly. Rotate the turntable slowly until the kelly is unscrewed from the drill pipe. Raise the kelly far enough so another length of drill pipe can be added to the pipe remaining in the hole. Reconnect the kelly and lower into the turntable. Start drilling again until you reach the end of the kelly. Keep repeating this procedure until you have drilled to the desired depth. You are now ready to complete the drilling operation. Proceed to remove the drill pipe, by pulling it out with the hoisting line. Finally, lower the casing with screen to the desired depth.

If you must change bits before the desired depth is reached, disconnect the kelly and attach the hoisting line to the drill pipe. Pull the drill pipe a length at a time, placing the bottom ends on a board to help keep them clean.

DRILLING PROBLEMS

Lost circulation is one difficulty you may encounter in drilling; sometimes it occurs in zones of high porosity, usually containing large supplies of water. A test of the well should be made whenever circulation is lost. Formations which draw off or absorb all or part of the circulating fluid offer problems ranging from minor inconveniences and loss of time to extreme conditions which render rotary drilling impossible.

Formations that contain joints and fissures—such as quartzite, sandstone, limestone, and dolemite—present problems arising from caving, abrasion, and complete loss of circulation.

Shale which is jointed and fissured seldom draws off an excessive amount of circulating mud. However, drilling fluid that is absorbed causes the shale to swell and heave, filling up the drill hole. This has been overcome by the use of special drilling fluids. This condition is rare and satisfactory drilling progress can usually be made by using a drilling fluid of high viscosity and weight.

Sands and gravels often absorb enough drilling fluid to hinder drilling progress. Fluid loss, which in most cases will be continuous, should be replaced with mud—not water. Water, when used to maintain sufficient volume for circulation, soon lowers the viscosity and weight of the mud-water mixture, and caving results.

There are two methods of regaining lost circulation. The method found most satisfactory in water well drilling is to drill through the zone of lost circulation and to set a string of well casings somewhat below the porous zone. The chief requirement for this procedure is a plentiful supply of water to circulate the cuttings away from the bit and into the formation. Mud is desirable but the quantity needed usually precludes its use. When using water to carry off the drill cuttings, always remember to continue to operate the pump for a few minutes after drilling has stopped. This flushes the cuttings out of the hole and prevents the drill pipe from sticking when it is stopped to make a connection. In extreme cases where it is necessary to drill as much as 100 feet or more through this type of formation, a small quantity of mud is spotted around and above the bit while an additional joint of pipe is installed in the drilling string. This prevents excessive settling-out of the drill cuttings and consequent sticking while the drill pipe is standing. When the bottom of the zone has been reached, drilling is continued into the underlying formation for about 50 feet to give room for cementing the casing.

When the casing has been run and cemented, ordinary rotary drilling procedure is resumed.

In the second method, circulation can usually be regained by mixing fibrous material with the drilling fluid. This material may be bought commercially, and may be obtained through supply. In an emergency, cottonseed hulls, bran, sawdust, shredded hay, or like substances may be substituted; these can contaminate fresh water supplies. In some cases the hole must be abandoned. If circulation is lost in cavernous limestone, the fluid level in the hole is checked and tested for fresh water.

A cheap, abundant supply of water is often the determing factor between a straight well hole and a loss of time, labor, and equipment.

Much depends on the experience and ability of the driller when drilling through difficult formations. Some of the important considerations for straight hole drilling are:

1. The diameter of the hole should never exceed twice the diameter of the drill pipe.
2. From 25 to 100 feet of drill collars should be used in the string.
3. Mud should be circulated at 50 gallons per minute per inch of bit diameter.
4. The speed of bit rotation should be at least 150 revolutions per minute.

These items that help to produce a straight hole are not possible with some small rigs. The driller will have to utilize the capabilities of the machine and his experience to keep the hole straight. The harder formations–especially those which are dipped and those that are broken and creviced–present many difficulties. Use only roller and 3- or 4-wing drag bits for this type of drilling. Fishtail and some of the single-cone roller bits are not suitable for any except the softest formations.

Crooked Holes

One way to detect crooked holes during drilling is to watch for wear on the drill pipe. If wear occurs at a set distance from the top of the ground, it indicates the hole was deflected at this point. It is not always easy to detect deflections of the bit and drill pipe while drilling, because the hole can be quite crooked without noticeably affecting the operation of the rig. The driller must be alert to any indication that the hole is going crooked.

To avoid crooked holes, the bits should be of a form and size that prevent undue eccentricity during rotation. They must be sharp, and dressed to proper gage. The drill collar which holds the bit to the lower end of the drill pipe must be large enough in diameter to hold the pipe centrally in the hole and to prevent the bit from working off to one side. Excessive bit pressures are to be avoided.

Another difficulty that may be encountered is the sticking or freezing of the drill pipe. An inexperienced drill operator may cause the drill pipe to stick by not circulating mud in the hole. The drill pipe is kept free in the hole by simultaneously rotating the pipe and circulating a mud-laden fluid. If either operation stops, only a limited time should elapse–depending upon the formation being penetrated–before pulling the bit into the casing (or out of the hole altogether, if no casing has been installed). Failure to do this often causes the drill pipe to become stuck due to sand and cuttings settling around it.

The drill pipe may also stick in some formations if lost mud is replaced with water and not mud. Formations are often encountered which drain off or absorb a certain amount of the drilling mud. If this mud is replaced with clear water to keep up the fluid level in the hole, the water thins the mud to a point where the mud exerts a cutting action on the walls of the hole and causes extensive caving around the drill pipe, fastening it securely in the hole.

Inadequate equipment may cause the drill pipe to stick. For example, a mud pump with insufficient capacity would not keep circulation moving fast enough to prevent drill cuttings from settling out and jamming the drill pipe.

BALLING UP may also cause the drill pipe to stick. Balling up is the accumulation of soft sticky shale or clay around the drill collar and bit. Occasionally, mud collars are formed which are forced up the hole by the pump action. This balling–if allowed to continue–forms a coating around the drill collar which sticks to the drill pipe securely when it is raised off the bottom. The usual cause of balling up is a high rate of penetration, combined with a speed of rotation insufficient to mix the drill cuttings thoroughly. To overcome these conditions the drill pipe is "spudded" frequently by raising it off the bottom 4 or 5 feet and dropping it while the pipe is rotating rapidly. If this is done, and if the rate of penetration is held to a speed which gives the circulating fluid time to mix the drill cuttings thoroughly, this source of trouble can be held to a minimum.

As mentioned before, loss of circulation may result in a stuck drill pipe. Loss of circulation is especially troublesome in porous limestone which contains much water. When one of these porous zones is penetrated by the drill, the pressure of the drilling mud causes it to drain off rapidly into the formation. The sudden reversal of circulation in the hole deposits the suspended drill cuttings around the drill pipe. This often happens so suddenly that there is no time to remove the drill pipe.

Recovery of Stuck Drill Pipe

Every precaution should be observed to prevent the drill pipe from sticking as only extreme scarcity of drill pipe justifies extensive recovery operations in drilling shallow wells. However, there are a few things which can be done successfully with the equipment at hand, depending upon how tightly and in what manner the drill pipe is stuck.

When the drill pipe becomes stuck by balling up while drilling in soft shale or clay, it can often be loosened by circulating clear water. An upward strain should be kept on the pipe while circulating the water.

When the pipe is stuck by sand or drill cuttings which have accumulated in the hole, circulation should be maintained with the heaviest mud obtainable. If at all possible the pipe should be worked. Any movement transmitted through the pipe, however slight, helps dislodge the sand particles into the mud stream, which carries them to the surface.

When heaving shale sticks to the drill pipe, probably the best method of loosening it is to spot oil along the portion of the pipe that is stuck. Move the oil every 2 hours with a few strokes of the pump. Keep a strain on the pipe. Oil should be used cautiously in drilling water wells, for often it contaminates adjoining wells in addition to the one in which used.

When a drill pipe is stuck through lack of circulation, there isn't much that can be done to recover the entire string of pipe. However, an attempt should be made to pull the pipe with jacks. Sometimes the pipe can be recovered by mixing the proper circulating fluid and circulating it while working the pipe with both the rotating and hoisting mechanisms. In some instances, the pipe can also be recovered by cutting it with a blasting charge in the bottom of the hole or about where the pipe is stuck.

Fishing

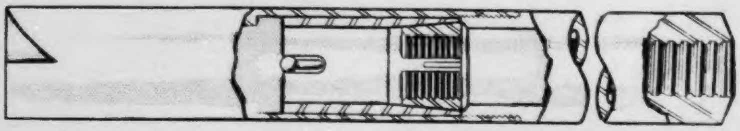
One of the big problems in well drilling is the recovery of tools lost in the well. Lost tools are recovered by fishing. The most frequent cause of tool loss in rotary drilling results from the drill pipe twisting off. Such "twist offs" usually occur near the lower end of the pipe. They may consist of a simple shearing off from the pipe, or of a fracture at a coupling. The accidental dropping of a drill pipe into a hole also calls for fishing. Among less common accidents requiring fishing is the dropping of tools such as slips or wrenches into the hole. The thing to remember when a break occurs is the exact depth of the break. This helps in locating the tops of the tools and coupling to them with a fishing tool. Recovery of lost drill pipes depends upon whether the driller can set the tool down on top of the pipes, and connect to them.

Some of the more common fishing tools are the tapered fishing tap, the die overshot, and the circulating-slip overshot (fig. 7-7).

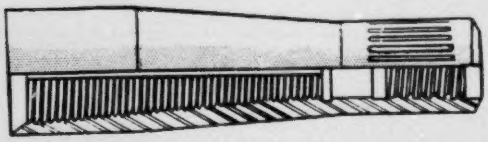
The TAPERED FISHING TAP, as its name implies, is a fluted tapered tap made of a heat-treated steel. Its action is similar to that of a machine tap, as it cuts its own threads when rotated, and thus grips the lost drill pipe.

The DIE OVERSHOT is a long-tapered die of heat-treated steel. When fitted over the lost drill pipe and rotated, the die overshot like the fishing tap also cuts its own threads. The tapered thread is fluted to permit the escape of metal cut by the threads. The upper end of the die has a thread to fit the drill pipe. The die is hollow but, as is also true of the tap die, circulation cannot be completed to the bottom of the hole through the lost pipes because the flutes allow the fluid to escape.

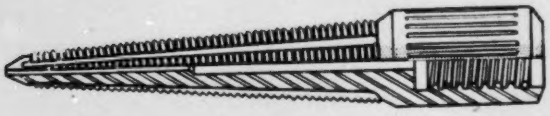
The CIRCULATING-SLIP OVERSHOT, as implied by its name, provides circulation through the lost pipe to assist removal when fishing. This tool is similar to the die overshot in its action but provides a watertight coupling between the drill pipes.



CIRCULATING SLIP OVERSHOT



DIE OVERSHOT



TAPERED TAP

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Figure 7-7.—Tap and overshot fishing tools.

In many shallow wells it is more economical to abandon the hole than it is to fish for the lost tools.

Swabbing

A swab means one thing to a sailor, and that is a mop used to get the deck clean. To a well driller, a SWAB is a device to clean the strainer or screen at the bottom of the well casing. The swab is run up and down in the well casing to create a suction which cleans the screen. The swab has a mandrel on which are fastened two rubber swabs or pistons. Be sure that the pistons fit closely but not tightly inside the casing. Swabs are attached to sinker bars that force them down into the well. Figure 7-8 shows a 4-inch swab. The swabs are alike in principle, but they are not the same in design, depending on their size.

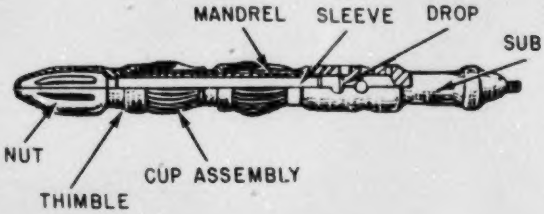

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Figure 7-8.—4-inch swab.

The 3-inch swab has no valve. Its pistons are made in two pieces. On the downstroke, one half of each piston moves upward and allows the fluid to pass through. On the upstroke this movable part falls back into position and prevents the passage of fluid, thus the piston functions as a check valve.

The 4-inch swab shown in figure 7-8 has a hollow mandrel, which is fitted with a ball valve. It has two cup-type pistons which are enclosed in a flexible wire basket. This swab is so designed that on the downstroke the ball valve opens to permit the passage of fluid, while on the upstroke the valve closes to prevent passage of the fluid.

PERCUSSION DRILLING

The percussion drilling or spudding rig operates on an entirely different principle than that of the rotary drilling rig. If you have drilled a hole in rock or concrete with a star drill and a sledge, you have an idea of the principle of the percussion drill. A percussion drill breaks up the rock or loosens other material by means of the impact of a heavy bit and drill stem which is lifted and dropped at regular intervals. The loosened material, known as drill cuttings, is removed from the hole by a bailer or sand pump. In drilling a dry hole (a hole in which surface water is lacking), water must be added to suspend the drill cuttings. It is necessary to replace the water taken out when the well is bailed.

A percussion drilling rig consists mainly of a mast, 2-drum winch, spudder, and engine. The SPUDDER is the heart of the rig. It raises and drops the drilling tools by means of two crank arms, two pitmans, and two shock-absorbing spudder arms. One drum of the winch controls the line for operating the drilling tools and the other drum controls the line for operating the bailer or sand pump. Figure 7-9 is a view of the skid-mounted No. 71 speed star percussion drill in operating position. It can also be mounted on a truck or trailer.

Normally, a skid-mounted spudding rig is operated by a crew of four—supervisor, operator, and two other crewmembers to steady the drill stem during mast raising and followup work during drilling. All crewmembers should wear hard hats, gloves, and safety shoes for protection against injury.

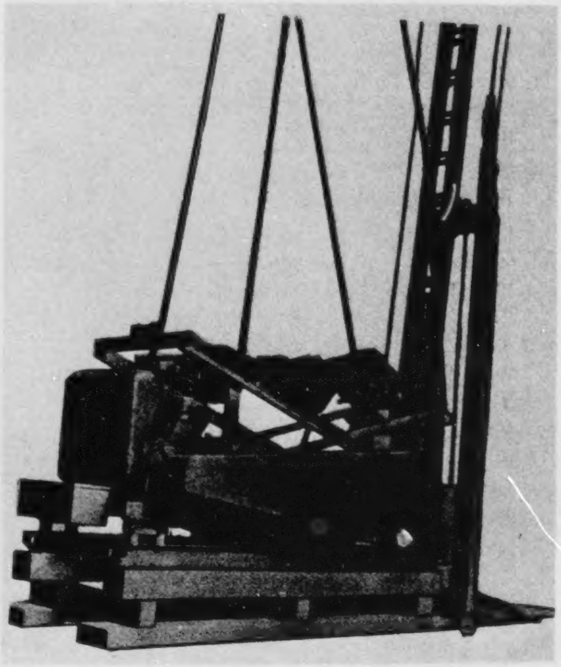

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Figure 7-9.—No. 71 speed star percussion drill.

Operating the Rig

Before starting to drill with your spudder, be sure to consult the manufacturer's manual. Briefly, the operation of a spudding rig is as follows: First, the machine is moved into position and leveled up in the same manner as the rotary machine. Once in position the drill is spudded-in. Since the tools work above the ground surface in spudding-in, the movement of the tools must be controlled carefully to avoid injury to the crew or damage to the drill. This includes clearing the work site of loose materials and preventing loss of tools down the bore hole.

In spudding-in, after securing the cable in the socket, do not forget to clean the grease and dirt from the threads on the drill stem and bit. To help you identify drilling tools, remember that the DRILL STEM (fig. 7-10) furnishes the necessary weight to the tool string. Drill stems are normally furnished in two sizes: 4-1/4 inches by 8 feet, and 4-1/4 inches by 16 feet. DRIVE CLAMPS (fig. 7-10), used in driving casing or

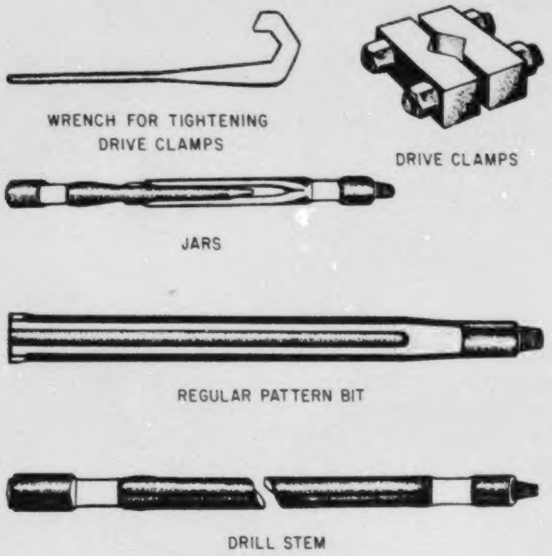

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Figure 7-10.–Drilling tools.

pipe, are attached to the square of the drill stem. Of course, the BIT is an especially important tool since it is the part that does the actual drilling. Bits of different shapes are made for different purposes. The regular-pattern bit is the best all-around bit (fig. 7-10). The four-wing, or star, bit is sometimes used for drilling holes that will not run straight because of underground formation.

With the cable secured in the socket, apply oil to the threads and shoulders of the pin to avoid rolling and chafing when unscrewed.

After screwing the cable socket and bit on the drill stem, you can proceed to tighten them. For the tightening operation, either chain tongs or the tool wrenches and chain bar are suitable.

In drilling hard rock it is good practice to carry drilling jars in the tool string at all times, so that they will be readily available when needed, to loosen stuck bits. DRILLING JARS (fig. 7-10) consist of two connecting links, with a pin on the upper link and a box on the lower end. Their position in the tool string is directly under the swivel socket. Jars are essential when drilling rock where the tools are likely to stick. New jars have a 6-inch stroke, which increases as the jar heads wear. The severe service required of jars makes it necessary to have them inspected daily for cracks or other damage.

Next, place the rope saver on the end of the swivel socket before raising the tools up the mast. A ROPE SAVER (fig. 7-11) is a wire-line attachment that slips over the neck of the swivel socket to prevent the cable from kinking when the tools are raised from any position other than vertical. It has a groove which the cable should follow when the tools are raised. Failure to use the rope saver may result in serious kinking of the cable at the socket neck.

The SWIVEL SOCKET (fig. 7-11) is attached to the drilling line which is attached directly with zinc to the swivel inside the socket. The purpose of the swivel socket in drilling is to allow the tool string to spin or turn after each blow. With a swivel socket, the bit seldom strikes more than one blow in the same place, thus eliminating some of the causes of crooked or out-of-round holes.

When the tools are swung on the mast, make sure you check to see that they hang directly down the center. When this requirement is met, set the tools down on the ground so as to mark the spot for drilling the hole.

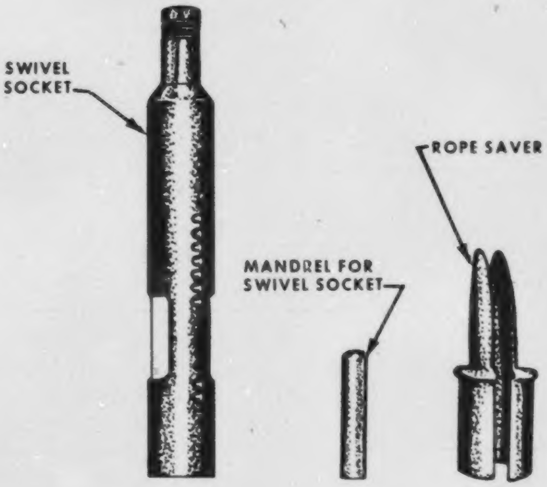

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Figure 7-11.–Rope socket and saver.

In starting a hole in soft, unconsolidated formations, dig a hole about 3 feet deep with a shovel. Let the tools down until the bit rests on the bottom of the hole; then fill the hole with water. Start the tools by throwing in the spudder beam clutch and run them slowly, guiding their movement by hand till they reach a depth of 6 or 8 feet. To start a hole in hard rock, dig or chisel out a hole 6 or 8 inches deep at the spot where the drill is to work. Set a length of pipe (6 to 8 feet) the same size as the hole to be drilled. Then brace and chain the pipe at the top to the mast, thereby providing a guide for the tools. If the pipe is securely fastened the tools can be run at a comparatively high drilling speed.

On the smaller percussion machines you will find two adjustments for the spudder mechanism. One is the multiple holes in the crank arms, and the other is the spring tension adjustment on the spudder shock-absorber springs.

Proper adjustment of the spudder assembly eliminates line whip, drill shock, and vibration, and increases the efficiency of the machine. Tension on the springs must not cause the spudder shaft to return to normal position with a quick snap as this causes a decided whip in the line, line wear, and excessive shock, and in most cases will spoil the drilling motion.

Operating speeds differ with the soil formation and depth of the hole. Run the drill only fast enough to permit smooth operation, and to allow the tools to drop with a clean, hard blow.

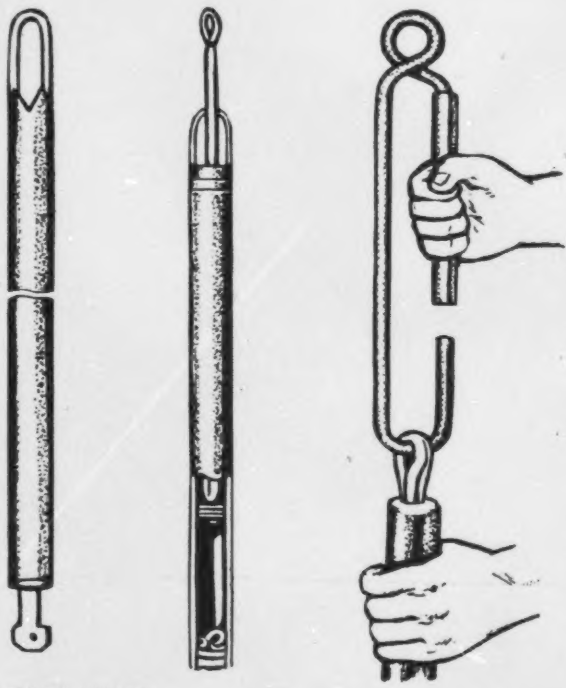
A tight line should be used in creviced and irregular formations. In hard rock and abrasive formations keep the drill bit to gage. If drilling is not progressing satisfactorily, yet the hole is straight and true, change to a shorter or longer stroke depending on the formation. A 32-inch stroke, with approximately 1700 pounds of tools, produces the best results in almost nine-tenths of all hard-rock drilling.

A WET hole is one in which there is more water than is required for drilling. A DRY hole is one in which excess water is cased off or absent during drilling. Drilling is faster in a dry hole.

When a percussion drilling machine is used, cuttings are removed by means of a bailer or vacuum sand pump as the hole is drilled. The DART-VALVE BAILER (fig. 7-12) is used for most bailing operations.

The dart valve opens when it contacts the cuttings at the bottom of the hole. A slight up-and-down motion of the bailer tends to draw the mud or cuttings into the bailer. When the bailer is withdrawn, the dart valve automatically closes, trapping the contents in the bailer.

The SAND PUMP is used in sand and gravel which the dart-valve bailer will not pick up (fig. 7-12). It is a hollow tube with a hinge-flap valve at the bottom and a plunger that works inside the tube. The sand line is attached to the top of the plunger rod. The sand pump is lowered to the bottom of the hole, allowing the plunger to travel to the bottom of the sand pump. When



DART-VALVE BAILER **SAND PUMP** **BAILER LINK**

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Figure 7-12.—Bailers.

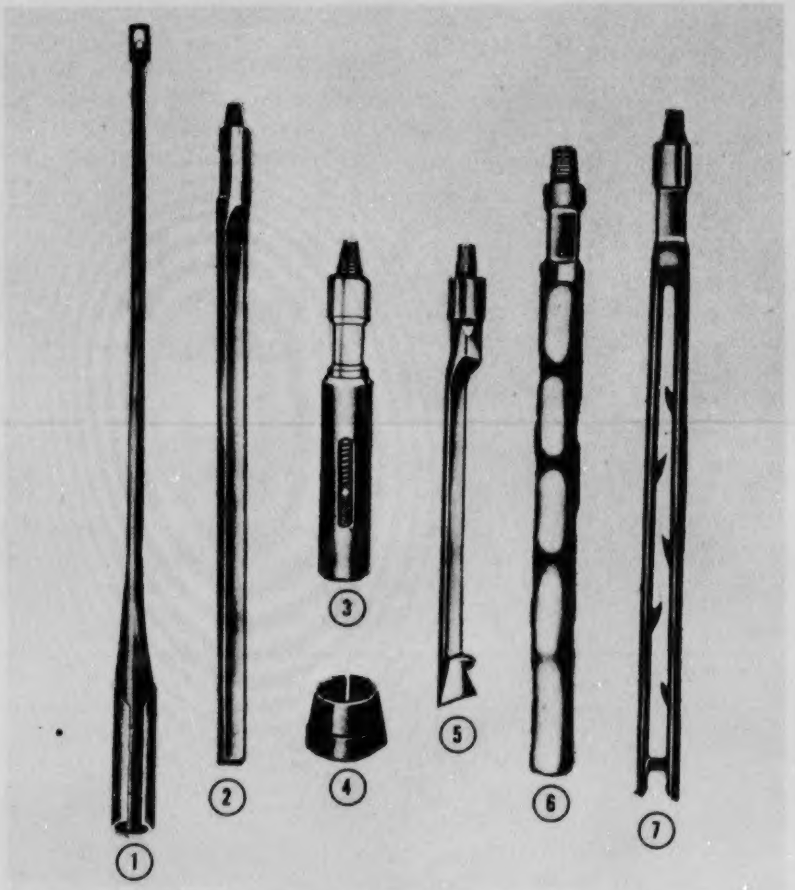
the plunger is raised, the material is sucked into the bailer. When the plunger reaches the top of the sand pump bail, it raises the pump and the hinge valve closes.

The BAILER LINK, also shown in figure 7-12, is used in making frequent changes from bailer to sand pump or bumper. Ordinarily, the sand line is tied to the top of the bailer link. A sliding sleeve is provided to open or close the bailer line (fig. 7-12) on one side.

Fishing

In percussion drilling, you will need to exercise care in fishing lost tools from the well. Various tools are used for fishing, some of which are pictured in figure 7-13.

The JAR BUMPER shown in figure 7-13 is used to loosen drilling tools that get stuck in the well. In using it, take a hard strain on the drilling line with the machine. Fasten the jar bumper to the drilling cable and lower it slowly until it



1. JAR BUMPER
2. SPUD
3. COMBINATION SOCKET
4. SLIPS FOR COMBINATION SOCKET
5. WALL HOOK
6. CORRUGATED FRICTION SOCKET
7. TWO-WING ROPE GRAB WITH LATCH-JACK BOTTOM

143.51

Figure 7-13.—Fishing tools.

touches the top of the tools. If it works freely without binding or sticking in this position, raise the jar bumper about 15 feet. Then let it fall–all the while keeping a hard strain on the drilling line. A few such drops usually will free the stuck tools unless they are buried deeply in sand or cave-ins.

If a bit comes unscrewed or breaks off in the hole, first try using a FRICTION SOCKET (fig. 7-13) to recover it. After setting your fishing tools down on top of the lost tool, drive down lightly with the jars. Then pull up your fishing tools and examine the marks and abrasions on the socket. Suppose the markings show that the socket went over the end of the lost tool. In such a case, your chances of recovering the tool are good. Run your socket in the hole again and drive it far enough over the lost tool that sufficient friction is provided to retrieve the tool. What if the markings show that the socket went down beside the lost tool–and not over it? In that case, don't try again at this point to retrieve the lost tool with the friction socket. Doing so will only drive the lost tool deeper into the well. The task now is to straighten the lost tool, and for this purpose use a SPUD (fig. 7-13). Alternating between the use of the spud and friction socket often brings results.

In using the spud as a straightening tool, first set it down alongside the lost tools and run the machine so that the fishing jars will hit both up and down. After about 20 to 30 minutes, remove the spud and make a trial run with the socket. If the tools still are not straight, set the end of the spud on top of them if possible, and drive it down its full length between the wall of the hole and the tools. Also, with the spud in this position, run the machine so the jars strike both up and down. Now make another trial with the socket.

Figure 7-13 also shows you a COMBINATION SOCKET, which is designed to catch the neck of the rope socket or pin of any bit or tool that comes unscrewed in the hole. It uses two different sets of SLIPS: one for catching the pin, another for catching the rope socket neck. Once you get a firm grip on the lost tool with a combination socket, nothing can shake it loose. Therefore, you should be sure before using the combination socket that the lost tool can be jarred loose by the weight of your fishing tools.

When the top of a lost tool has fallen into a cave-in in the side of a hole, the WALL HOOK (fig. 7-13) is the most efficient fishing tool for realining so the socket can be used. The technique involves running the wall hook down beside the tool and working the hook in behind it. This may be a bit difficult but usually can be done by running the tools at moderate speed, having the jars hit both up and down while you move the hook up gradually to the top of the tools. You will need patience, and even then may not succeed in recovering the tool. However, don't give up if the first attempt with the wall hook fails–keep trying, as results may be achieved after two or more attempts.

Another fishing tool you may need in percussion drilling is the two-wing rope grab with latch-jack bottom. The ROPE GRAB (fig. 7-13) is the fishing tool to use when your drilling line or sand line breaks and leaves the bailer or drilling tools in the hole, with the line on top of the bailer or drilling tools.

WELL DEVELOPMENT AND COMPLETION

Once an aquifer has been tapped by a borehole, the important and essential phase of completion and development must be accomplished in order to assure maximum yield under sanitary conditions. Well development and completion involves setting the casing and screens, removal of the drilling fluid, stabilization of the aquifer by removal of a predetermined percentage of the fines, grouting, and sterilization of the well.

The first operation after drilling the hole is to set the screens and casing. The casing prevents collapse of the borehole walls in unconsolidated formations. The screens prevent collapse of the borehole wall in the aquifer while allowing water to enter the casing freely.

When the screens and casing have been set the well is ready for development. Development is accomplished by removing the drilling fluid from the aquifer and the employment of any means that will induce an alternating flow of water in and out through the screens. This action stirs up the unconsolidated material in the aquifer and allows removal of the finer particles. Gradually, the coarsest particles become stabilized around the screens and the last vestiges of drilling fluid are removed, permitting the well to yield its maximum capacity.

There are a variety of methods used in setting screens, removing drilling fluid, and developing aquifers. The method used for doing each is often determined by the tools and equipment available.

When development of a well is complete, it may be necessary to grout as a sanitary protective measure. Grouting is accomplished by cementing the annular space between the well wall and casing in order to prevent seepage of surface water or contaminated water into the aquifer.

A completed well has two elements: the conduit (cased portion) and the intake (screened portion). The diameter of the cased portion significantly affects the cost and must be selected to accommodate the pump to be used. Additionally, the intake portion, though not necessarily the same diameter as the cased portion, must be sufficient to assure good hydraulic efficiency. The casing diameter should be two and never less than one nominal size larger than the pump.

A screen should be selected that will allow water to enter the well at low velocity and, at the same time, prevent sand from entering. A screen should never be larger in diameter than the casing above it so that, if necessary, you can pull the screen for cleaning or replacement. If there are no screens available, an expedient type screen can be made by slotting the lower casing.

In consolidated rock, the intake portion is the open borehole. Good engineering demands that drilling be completed to the bottom of an aquifer. This permits more available drawdown (distance from static water level to pump) and increased yield. It also makes a thicker aquifer available for the intake portion of the well.

A well screen's length is chosen in relation to the thickness of the aquifer. Experience has shown that screening the bottom one-third of a water table aquifer produces best results. At best, this should be a happy medium between two desired results: high specific capacity from using the longest screen possible and maximum available drawdown from using the shortest screen possible.

Well screen slot openings are determined by the gradation of the aquifer which is most accurately indicated by a sieve analysis of the material. The slot sizes are chosen to allow the fines to pass through during development and the coarse particles to be retained. Retention of a stabilized thickness of coarse material in the immediate vicinity of the screen increases the permeability and prevents the entrance of finer particles after the well has been developed. Well screen slot openings should retain 40% of natural foundation. If 40% cannot be retained, an artificial gravel pack should be used which should retain 70%.

Variation in screen diameters does not appreciably affect the well yield. Doubling the intake diameter will increase specific capacity about 10 percent. The screen diameter should be adequate to control the entrance velocity of the water. Tests have proven that an entrance velocity of 0.1 ft/sec or less results in negligible friction losses in screen openings, minimum incrustation, and a minimum rate of corrosion. Entrance velocity is calculated by dividing expected yield by total area of screen openings. If greater than 0.1 ft/sec, intake diameter should be increased: if less than 0.1 ft/sec, intake diameter should be reduced.

CHAPTER 8

CONSTRUCTION AND AUTOMOTIVE EQUIPMENT POOL MANAGEMENT

An equipment pool consists of construction equipment and automotive vehicles under control of the Equipment Company of a Naval Mobile Construction Battalion or the Transportation Division of a Public Works Department.

The Navy has an enormous investment in both construction and transportation equipment. In addition to the original purchase cost, there is the expense of operation, repair, and upkeep of this equipment.

In the Naval Construction Force, the first class and chief petty officers are responsible not only for seeing that the equipment is efficiently used, but also insuring the equipment is properly maintained. The following sections outline the EO's responsibilities involving management of a construction and automotive equipment pool at the Naval Mobile Construction Battalion level.

SITE SELECTION

The selection of the site for a construction and automotive equipment pool depends largely upon the mission of your activity, as well as the terrain and climatic conditions of the area. Where possible, you will want to locate the pool near enough to the center of activity to allow the equipment to be used economically and efficiently. If terrain conditions do not provide such a desired location, a decision must be made either to move the pool to a site away from the center of activity or to engage in time-consuming excavation.

The importance of good drainage must not be overlooked. In some instances, the site you choose may already have natural drainage; another site may need an extensive drainage system.

Make sure you allow adequate space for equipment. The site plan chosen should allow for future expansion. It is advisable to allow sufficient space for parking equipment; this area should have a loading ramp for loading equipment on lowbed trailers.

Consider the entrances and exits. They should be laid out to allow for a smooth flow of traffic. In addition, entrances and exits should be well marked or posted and wide enough to accommodate the largest piece of construction equipment in the pool.

Give careful consideration to the location of fuel storage tanks and parking of fuel trucks. Proper location will allow the equipment to top off or fill up at the end of each workday, and permit traffic to flow in and out of the pool area without congestion.

When initially set up, most of the equipment pool areas at advanced bases have hard dirt surfaces. With a continuous flow of heavy equipment in and out of the pool area, these surfaces will soon become extremely rough. If the pool area is allowed to remain in that condition, equipment will be subjected to unnecessary wear and tear. A dirt surface will require frequent maintenance which will consist mostly of filling, smoothing, and grading.

If the camp is to be established for a long period of time, the parking area should be covered with crushed stone or other material, if available locally; this covering will provide a more stable base than the dirt surface. As a further improvement, cover some sections of the pool area with asphalt.

When designating areas for the various types of equipment and vehicles, it is well to take into consideration the approximate number of daily requests that may be expected for each type of equipment. Place the equipment that will be requested most frequently in a location that is most accessible. This will provide a uniform flow of traffic in and out of the pool area with the least disruption.

If located at an advanced base in a combat zone, disperse the vehicles to lessen possible damage from rocket or mortar attack. Vehicles parked in a neat, close file or rows present large targets. If a pool receives incoming rounds, you can expect damage to some of the vehicles. A good supervisor will coordinate with the maintenance shop to insure that sufficient spare parts are available for emergency repairs. This will speed up recovery time in getting the vehicles back on the job.

Another consideration is the location of the maintenance and repairs shops. Normally these shops will be located in the vicinity of the construction and automotive equipment area. It is also feasible to locate the dispatcher and Equipment Company office in the same general area.

POOL MANAGEMENT

To qualify for EO1 or EOC, you are expected to know management techniques and concepts and apply them in the the supervision and utilization of a construction and automotive equipment pool.

The basic objectives of managing a construction and automotive equipment pool are to obtain maximum available safe and serviceable equipment and to insure the maximum service life of the equipment. To accomplish these objectives you will need to apply the basic management procedures discussed in the following paragraphs.

PLANNING AND SCHEDULING

The time and thought you devote to planning and scheduling will pay large dividends in terms of time and effort saved. Your main sources of information will be current NAVFAC instructions, regimental instructions, battalion directives, official manuals, and special publications related to planning and scheduling. Such sources will provide information that will be useful in establishing complete and accurate inventory records, setting up preventive maintenance schedules, and rescheduling and assigning shop work.

ORGANIZATION

The organizational structure of an equipment pool may be relatively simple, but it must be a well-balanced structure.

Draw up and display a construction and automotive equipment pool organization chart which will aid in planning, as well as show the crew where and how if fits into the organization.

COORDINATION

Efficient management of the construction and automotive equipment pool may require coordination with other activities, such as the supply division and maintenance division. One way to help insure proper coordination is to maintain an efficient tickler file in your office. The file should provide a means of reminding you to coordinate jobs and deadlines with the necessary supporting activities so that time schedules will be maintained and equipment will be available when needed.

CONTROL

In a broad sense, control encompasses all functions of management and comprises those specific functions which enable management to effectively and efficiently direct the efforts of the organization toward the accomplishment of planned objectives. When applied to construction and automotive equipment pool management, those specific functions that monitor and control work input include productivity, material expenditures, equipment downtime, and quality of workmanship.

Control over productivity is exercised by management through the use of job-time standards. Estimates based on past performance are applied to all project operations and must be compared by the supervisor with the actual time taken to complete the project.

Control over material expenditures is exercised primarily through direct line supervision.

Control over downtime must be exercised through proper operation and maintenance of the equipment. As the supervisor of these operators, you must see that they comply and their efforts produce the required results, minimizing downtime.

Control over quality of workmanship is exercised primarily through direct line supervision of the operators. Supervisors and crew leaders check the operating techniques through various stages of the work project, and if necessary, introduce additional training and instruction.

REPORTS AND PERFORMANCE EVALUATION

Effective management control depends to a large extent on management having available essential data on all phases of the operational effort. These data, together with performance standards, enable the various supervisory levels of management to make proper decisions and take necessary action to direct and control the effort. It is a primary function of the supervisor to analyze and evaluate the data collected to determine the basic causes of operational and maintenance variances and take necessary corrective action.

PREVENTIVE MAINTENANCE

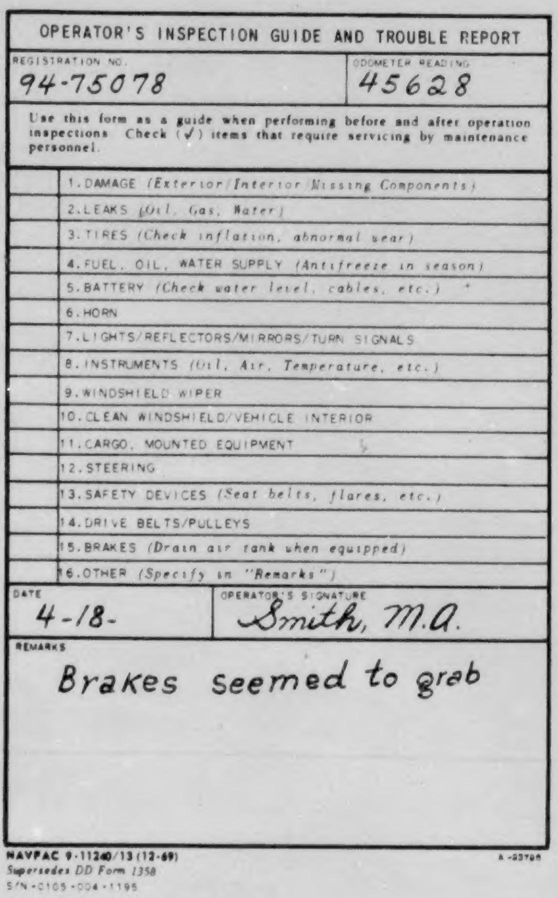
The purpose of preventive maintenance is to keep equipment in safe and serviceable condition at all times at minimum costs and to detect and correct minor deficiencies before they develop into major repairs. Equipment is considered in safe and serviceable condition when operation will not cause damage to the equipment, or create a safety hazard. Safe and serviceable operating condition may be determined by:

1. A visual or operational inspection of units or subassemblies to determine whether they are properly tightened, and properly lubricated if required, and that all components are in their correct relative positions and functioning properly.

2. A visual inspection of units, assemblies or subassemblies to determine whether they are excessively worn (wear beyond serviceable limits).

The operators are the first line of defense against equipment wear, failure, and damage. Equipment must be inspected systematically before and after operation so that defects may be discovered before they result in serious damage or failure. Defects discovered during inspections or during operation of equipment should be noted on the Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13 (fig. 8-1) or Operator's Daily PM Report, NAVFAC 11260/4 (fig. 8-2), and reported as soon as operation ceases. The operator must stop operation immediately if a defect is observed that could damage the equipment or render it unsafe.

Effective preventive maintenance services require a systematic scheduling program that will make equipment available for mechanical inspections, lubrications, adjustments, and necessary repairs at predetermined intervals. Thus, downtime and resultant disruptions of work schedules, due to equipment failures, are minimized. In addition, effective planning and scheduling will insure that the major portion of the shop workload of the mechanics will be uniform and balanced, minimizing the required work force and maximizing the application of the work force to productive effort. It should be recognized that there is an economical point at which the random failures of equipment can be reduced by preventive maintenance. Experience indicates that an optimum ratio of three scheduled to one interim repair, excluding tire and battery replacement or repair, can be



OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT

REGISTRATION NO.	ODOMETER READING
94-75078	45628

Use this form as a guide when performing before and after operation inspections. Check (✓) items that require servicing by maintenance personnel.

☐	1. DAMAGE *(Exterior/Interior/Missing Components)*
☐	2. LEAKS *(Oil, Gas, Water)*
☐	3. TIRES *(Check inflation, abnormal wear)*
☐	4. FUEL, OIL, WATER SUPPLY *(Antifreeze in season)*
☐	5. BATTERY *(Check water level, cables, etc.)*
☐	6. HORN
☐	7. LIGHTS/REFLECTORS/MIRRORS/TURN SIGNALS
☐	8. INSTRUMENTS *(Oil, Air, Temperature, etc.)*
☐	9. WINDSHIELD WIPER
☐	10. CLEAN WINDSHIELD/VEHICLE INTERIOR
☐	11. CARGO, MOUNTED EQUIPMENT
☐	12. STEERING
☐	13. SAFETY DEVICES *(Seat belts, flares, etc.)*
☐	14. DRIVE BELTS/PULLEYS
☐	15. BRAKES *(Drain air tank when equipped)*
☐	16. OTHER *(Specify in "Remarks")*

DATE	OPERATOR'S SIGNATURE
4-18-	Smith, M.A.

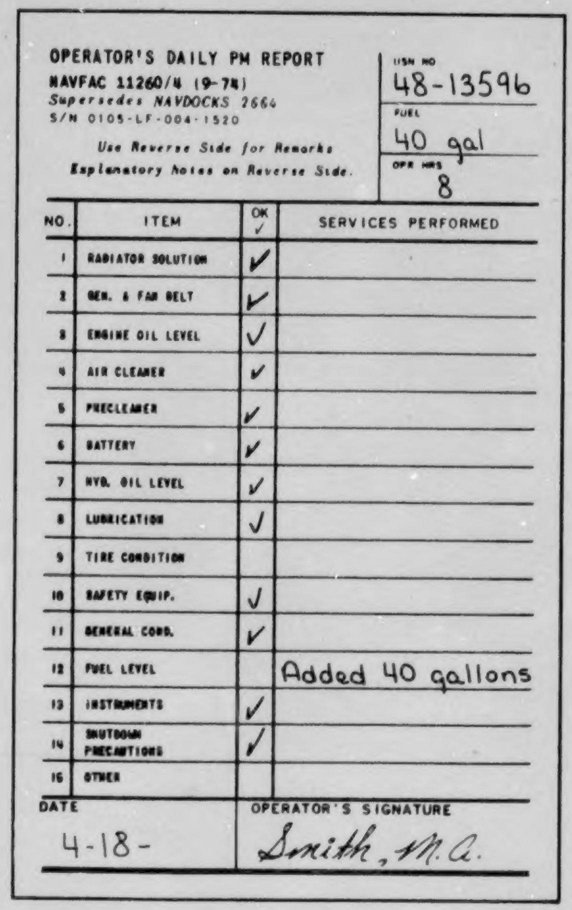
REMARKS

Brakes seemed to grab

NAVFAC 9-11240/13 (12-69)
Supersedes DD Form 1358
S/N-0105-004-1195
A-33798

29.50

Figure 8-1.—Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13.



OPERATOR'S DAILY PM REPORT
NAVFAC 11260/4 (9-74)
Supersedes NAVDOCKS 2664
S/N 0105-LF-004-1520

Use Reverse Side for Remarks
Explanatory Notes on Reverse Side.

USN NO: 48-13596
FUEL: 40 gal
OPR HRS: 8

NO.	ITEM	OK ✓	SERVICES PERFORMED
1	RADIATOR SOLUTION	✓	
2	GEN. & FAN BELT	✓	
3	ENGINE OIL LEVEL	✓	
4	AIR CLEANER	✓	
5	PRECLEANER	✓	
6	BATTERY	✓	
7	HYD. OIL LEVEL	✓	
8	LUBRICATION	✓	
9	TIRE CONDITION		
10	SAFETY EQUIP.	✓	
11	GENERAL COND.	✓	
12	FUEL LEVEL		Added 40 gallons
13	INSTRUMENTS	✓	
14	SHUTDOWN PRECAUTIONS	✓	
15	OTHER		

DATE	OPERATOR'S SIGNATURE
4-18-	Smith, M.A.

81.323

Figure 8-2.—Operator's Daily PM Report, NAVFAC 11260/4.

achieved economically. At this rate, approximately 75 percent of the work can be planned and scheduled.

Preventive maintenance schedules depend on whether your unit is a part of the shore establishment (Public Works) or the operating forces (NCF units). Maintenance scheduling for shore activities is in compliance with the equipment manufacturers' recommendations and any additional guidelines established by NAVFAC. You should be concerned with the maintenance schedules of only those items of equipment that require changes in their present schedule due to an increase or decrease in their use or with new receipts. Detailed guidelines for scheduling PM services at shore activities are contained in Part II of *Management of Transportation Equipment*, NAVFAC P-300.

In addition to scheduled maintenance, vehicles and equipment at shore activities must be inspected for safety and serviceability at least every 6 months or 6000 miles, whichever occurs first. The inspections prevent the deterioration of a vehicle or item of equipment which has little or no usage.

The maintenance functions performed by the operating forces must assure a higher level of equipment reliability than the shore activity. The operating forces use a 40-day PM schedule to maintain the equipment in a high state of readiness and insure rapid mobilization. This means that every item of equipment is inspected at least every 40 working days and any discrepancies noted are corrected immediately. Detailed guidelines for scheduling PM services for Naval Construction Force activities are contained in chapter 4 of NAVFAC P-404, *Naval Construction Force Equipment Management Manual.*

COLLATERAL EQUIPAGE

To make a basic item of equipment complete and self-sustaining often requires additional items, know as collateral equipage. There are two basic types of collateral equipage: component and tactical.

COMPONENT COLLATERAL EQUIPAGE

Component collateral equipage consists of items such as hoses for pumps, bits for earth augers, etc. These items are normally procured on the same contract as the basic machine. Manufacturers' manuals normally contain listings of collateral equipage; however, caution should be exercised as the Navy rarely procures all the collateral equipage available for any particular machine. Activities unable to determine the correct collateral equipage for an item of equipment should request assistance from the Civil Engineer Support Office (CESO), Port Hueneme.

TACTICAL COLLATERAL EQUIPAGE

Tactical collateral equipage consists of those items common to the equipment, but are not necessary for the performance of the work the equipment is designed to do, such as blitz cans, fire extinguishers, top canvases, and tarpaulins.

CONTROL OF COLLATERAL EQUIPAGE

As the first class or chief petty officer in charge of transportation, you should insure that all collateral equipage is either properly mounted on the equipment or stored in a secure location. This can be accomplished by maintaining an accurate, up-to-date location listing of your unit's collateral equipage. You should also inventory the collateral equipage assigned to a piece of equipment while that USN number equipment is in the shop for each scheduled PM. If you find shortages, and replacements are required, order the items, and insure that appropriate NAVSUP Form 1250 copies are maintained for each requisition submitted.

Check out component collateral equipage to the operator or crew leader by signature on an as-needed basis. Insure that the person who has custody is aware that he will be held responsible for loss or damage of the collateral equipage for which he is accountable.

TRANSFER OR DISPOSAL

Unless otherwise instructed in the shipping directive, all collateral equipage for a particular machine is properly prepared for shipment and transferred along with that machine. All small items are placed in a separate box, which is stenciled with the USN number and securely attached to the equipment. When an item of equipment is replaced with a "like" machine, collateral equipage should be reviewed for retention for use on the new machine. A full allowance of collateral equipage should be maintained. Extra and obsolete collateral equipage should be disposed of along with the basic machine.

RECORDS AND REPORTS

You may not like paperwork, but you will find that the time spent in careful preparation of records and reports is well worth the effort. Reports reflect strengths and weaknesses, indicate rates of job progress, provide information useful in preparing work schedules, and so on. Records are valuable as a record of work performed and will give you the number of man-hours required to accomplish a particular project. Among other things, records aid in estimating the amount of materials used and the amount needed as replacements. Whether a record or report is to be submitted through official channels or is to be kept for your own personal use, make sure the information is accurate. As a supervisor, you can handle the preparation of records and reports yourself or assign the duty to one of your men. In either case, see that the work is done properly and kept up to date.

Your dispatching office is a very important part of the construction and automotive equipment pool. Dispatching and dispatching forms are discussed in *Equipment Operator 3 & 2,* NAVEDTRA 10640-H. It is your responsibility to see that the dispatcher keeps the dispatching forms and records indexed in accordance with guidelines prescribed in the Department of the Navy *Standard Subject Identification Codes Manual,* SECNAV Instruction 5210.11. A copy of this instuction is available in the personnel office and in the technical library. The classification systems in this manual are designed to meet the needs of the entire Department of the Navy for a single, standard subject scheme to be used in numbering, arranging, filing, and referencing various types of Navy documents by subject. The following codes are likely to be used most often:

11200 - General

11210 - Highway and Roads

11220 - Bridges

11230 - Railway

11240 - Automotive

11260 - Heavy Equipment

11261 - Construction-Type

11262 - Heavy Weight-Lifting

The Standard Subject Identification Codes system is generally employed by large shore activities, such as Public Works Departments, SEABEE Centers, Brigade Headquarters, and so on. For smaller mobile units, such as the battalion, the dispatcher or supervisor may devise his own indexing system to suit the volume of records and forms handled.

Make certain that each piece of transportation equipment dispatched by your dispatcher carries the following forms:

Vehicle/Equipment Request and Record, NAVFAC 9-11240/1.

Operator's Report of Motor Vehicle Accident, Standard Form 91.

Accident-Identification Card, DD Form 518.

Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13.

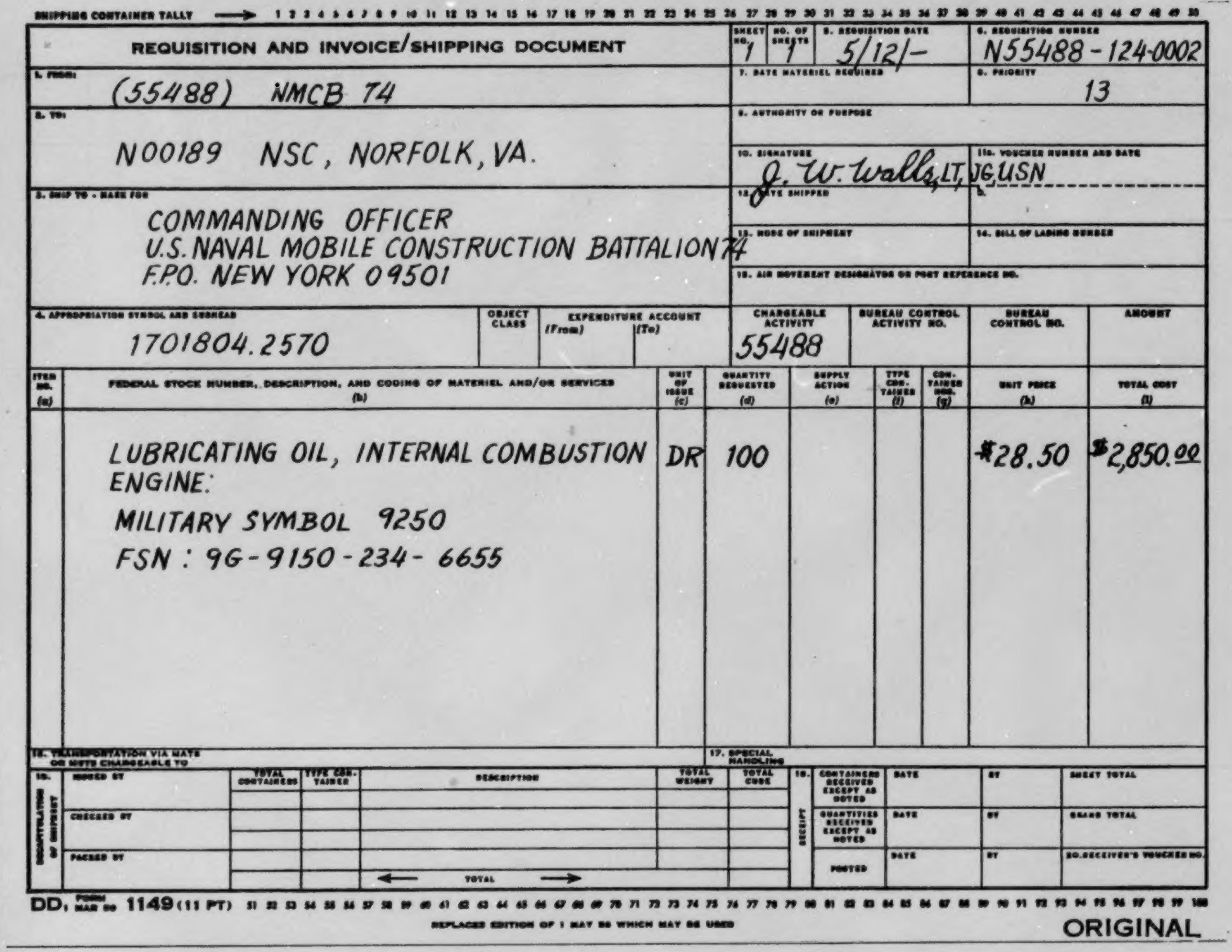
At the time a piece of construction equipment is dispatched, the operator should be provided with an Operator's Daily PM Report, Construction and Allied Equipment, NAVFAC 11260/4.

To order new supplies of fuels and lubricants, you will use the Requisition and Invoice/Shipping Document, DD Form 1149 (fig. 8-3). This requisition is limited to a single page and must contain no more than nine line items; for additional items, use additional sheets.

The records and reports discussed above are prepared on standard forms. Your work may also involve various nonstandard records and reports. Nonstandard records and reports are of local design and the forms do not carry an identifying number.

A daily fuel issue log of local design is maintained by the dispatcher to provide fuel and oil usage data by USN number. The dispatcher transfers the information to a monthly fuel log, which in turn is used to accumulate the data required for preparation of the monthly fuel report sent to the appropriate command.

A Job Order Progress Record Sheet is useful for presenting the daily status of all work projects utilizing equipment from the construction and automotive equipment pool.



SHIPPING CONTAINER TALLY → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

REQUISITION AND INVOICE/SHIPPING DOCUMENT

SHEET NO. 1

NO. OF SHEETS 1

5. REQUISITION DATE 5/12/—

6. REQUISITION NUMBER N55488 - 124-0002

1. FROM: (55488) NMCB 74

7. DATE MATERIEL REQUIRED

8. PRIORITY 13

2. TO: N00189 NSC, NORFOLK, VA.

9. AUTHORITY OR PURPOSE

10. SIGNATURE J. W. Walls, LT, JG, USN

11a. VOUCHER NUMBER AND DATE

12. DATE SHIPPED

b.

3. SHIP TO - MARK FOR
COMMANDING OFFICER
U.S. NAVAL MOBILE CONSTRUCTION BATTALION 74
F.P.O. NEW YORK 09501

13. MODE OF SHIPMENT

14. BILL OF LADING NUMBER

15. AIR MOVEMENT DESIGNATOR OR PORT REFERENCE NO.

4. APPROPRIATION SYMBOL AND SUBHEAD	OBJECT CLASS	EXPENDITURE ACCOUNT (From)	(To)	CHARGEABLE ACTIVITY	BUREAU CONTROL ACTIVITY NO.	BUREAU CONTROL NO.	AMOUNT
1701804.2570				55488			

ITEM NO. (a)	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CON-TAINER (f)	CON-TAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
	LUBRICATING OIL, INTERNAL COMBUSTION ENGINE: MILITARY SYMBOL 9250 FSN: 9G-9150-234-6655	DR	100				$28.50	$2,850.00

16. TRANSPORTATION VIA MATS OR MSTS CHARGEABLE TO

17. SPECIAL HANDLING

18. RECAPITULATION OF SHIPMENT	TOTAL CONTAINERS	TYPE CON-TAINER	DESCRIPTION	TOTAL WEIGHT	TOTAL CUBE
MARKED BY					
CHECKED BY					
PACKED BY			← TOTAL →		

19. RECEIPT	DATE	BY	
CONTAINERS RECEIVED EXCEPT AS NOTED			SHEET TOTAL
QUANTITIES RECEIVED EXCEPT AS NOTED			GRAND TOTAL
POSTED			20. RECEIVER'S VOUCHER NO.

DD FORM 1 MAR 60 1149 (11 PT) 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

REPLACES EDITION OF 1 MAY 58 WHICH MAY BE USED

ORIGINAL

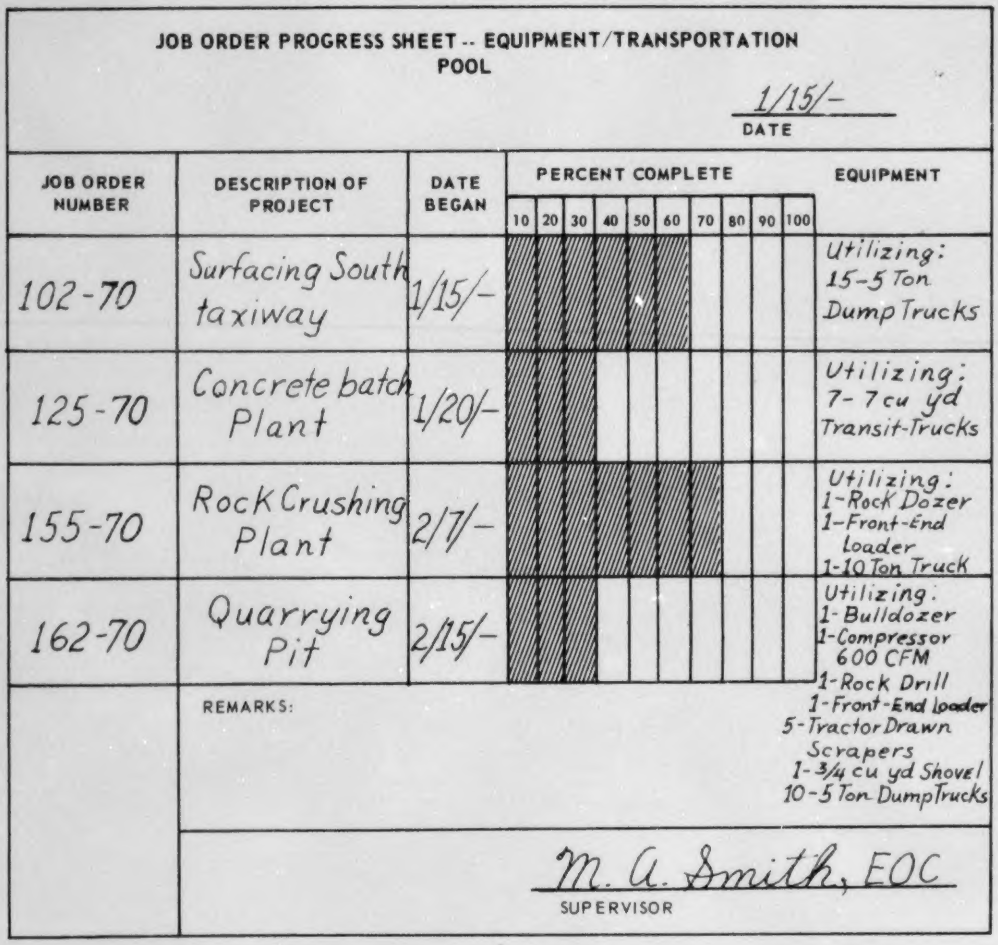
43.3

Figure 8-3.—Requisition and Invoice/Shipping Document, DD Form 1149.

At some activities a progress record sheet, such as that shown in figure 8-4, is made up at the close of each working day and submitted to the company office. On the record sheet, all uncompleted job orders are listed by number; a brief description of each job is also given, together with the date the job order was received. A chart provides space for indicating the percentage of work completed on each project. The "Remarks" column of the record sheet may be used to indicate the types of equipment, and the number of pieces of each type, being used on each project. Be sure and retain a copy of the record sheet for your files.

Some activities require a Daily Man-Hour Report that gives you an overall picture of the way in which the working day is spent. A sample of a daily man-hour is illustrated in figure 8-5.

For your own personal use, you will find it advantageous to maintain a Material Expended Record, which provides a means of keeping track of the status of materials. It might be



JOB ORDER PROGRESS SHEET -- EQUIPMENT/TRANSPORTATION POOL

1/15/-
DATE

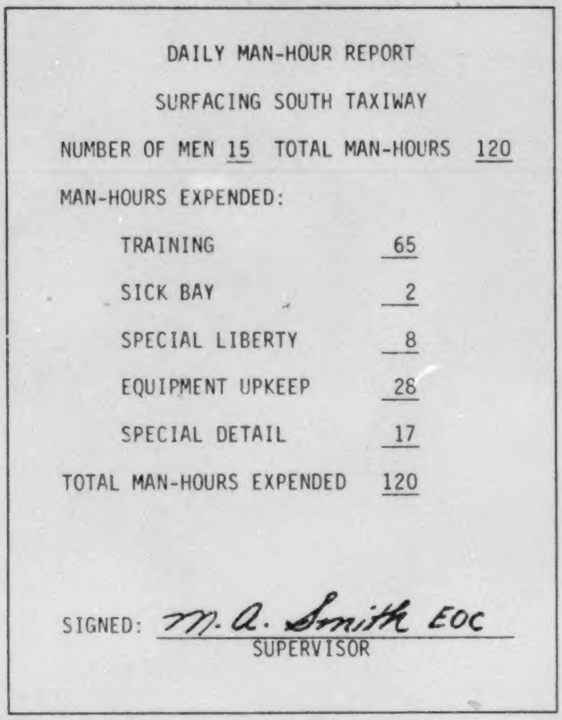
JOB ORDER NUMBER	DESCRIPTION OF PROJECT	DATE BEGAN	PERCENT COMPLETE										EQUIPMENT
			10	20	30	40	50	60	70	80	90	100	
102-70	Surfacing South taxiway	1/15/-	▨	▨	▨	▨	▨	▨					Utilizing: 15-5 Ton Dump Trucks
125-70	Concrete batch Plant	1/20/-	▨	▨	▨								Utilizing: 7- 7 cu yd Transit-Trucks
155-70	Rock Crushing Plant	2/7/-	▨	▨	▨	▨	▨	▨	▨				Utilizing: 1-Rock Dozer 1-Front-End Loader 1-10 Ton Truck
162-70	Quarrying Pit	2/15/-	▨	▨	▨								Utilizing: 1-Bulldozer 1-Compressor 600 CFM 1-Rock Drill 1-Front-End loader 5-Tractor Drawn Scrapers 1-3/4 cu yd Shovel 10-5 Ton DumpTrucks

REMARKS:

M. A. Smith, EOC
SUPERVISOR

18.3

Figure 8-4.—Job order progress record sheet.



DAILY MAN-HOUR REPORT

SURFACING SOUTH TAXIWAY

NUMBER OF MEN 15 TOTAL MAN-HOURS 120

MAN-HOURS EXPENDED:

TRAINING	65
SICK BAY	2
SPECIAL LIBERTY	8
EQUIPMENT UPKEEP	28
SPECIAL DETAIL	17
TOTAL MAN-HOURS EXPENDED	120

SIGNED: M. A. Smith EOC
SUPERVISOR

18.4

Figure 8-5.—Daily man-hour report.

noted that a record of this kind is utterly worthless unless it is faithfully maintained. This record can best be kept in a notebook, with a separate section of the notebook being used for each type of material your crew uses. The information on a material expended record should include the date the material is received, the amount received, the date it is expended, the amount expended, the job order on which the material is used, and the balance remaining on hand. Figure 8-6 shows a suggested method of logging this information.

Another personal record that you will find useful is the Equipment Status Board, which provides a means of listing, by USN number, equipment assigned to the pool. It shows the daily status of all equipment. Figure 8-7 illustrates one method that may be used. Note the use of a color code in the lower right portion of the figure. This status board must be maintained daily by your dispatcher to show where the equipment is located—whether it is assigned to a particular project or operator, or is in the maintenance shop for repairs.

LICENSING PROCEDURES

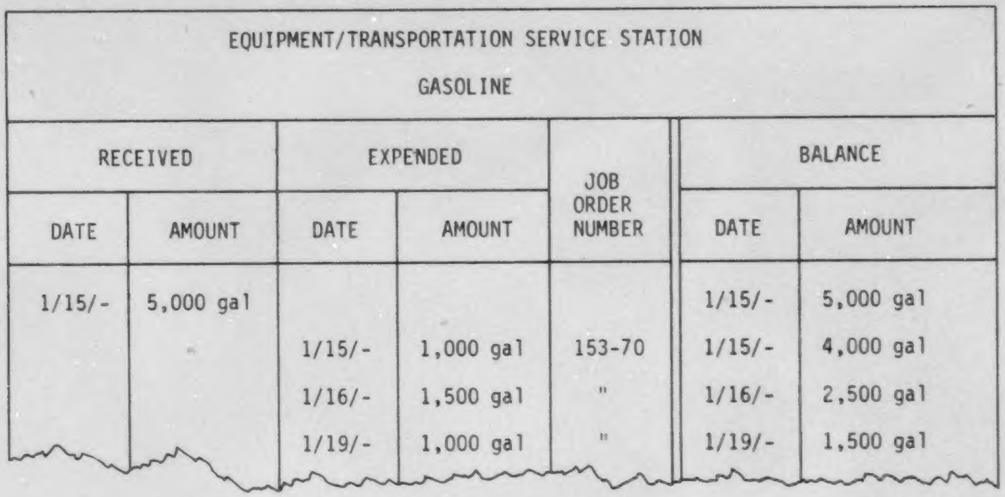
All Navy personnel (military or civilian) assigned duties that involve driving and operating government-owned or rental equipment must be qualified and licensed in accordance with the provisions of chapter 1 of *Management of Transportation Equipment*, NAVFAC P-300 or chapter 3, *Naval Construction Force Equipment Management Manual*, P-404. Under no circumstances will a vehicle be dispatched to a person who does not have a valid U.S. Government operator's license covering the size and type of vehicle requested. The proper license form for automotive vehicles and materials-handling equipment (MHE) is the U.S. Government Motor Vehicle Operator's Identification Card, Standard Form 46.

The proper license for other types of equipment is the Construction Equipment Operator License, NAVFAC Form 11260/2. As an EO1 or EOC, you may be responsible for the examining and licensing of operators. As the license examiner, you will be the qualified representative of your commanding officer.

LICENSE ISSUANCE

Government licenses should be issued or validated only when all requirements are complied with in writing, by an authorized examiner. Military personnel are not authorized to drive government vehicles off base at anytime in CONUS unless they hold both the SF 46 and a valid state license. Exceptions may be granted by state or local enforcement officers.

Personnel with a valid, current SF-46 or NAVFAC 11260/2 should be recognized as fully qualified to operate the equipment specified on their licenses, regardless of where the license was issued. However, units can, for any reason, require a license holder to satisfactorily complete an equipment familiarity checkout



EQUIPMENT/TRANSPORTATION SERVICE STATION

GASOLINE

RECEIVED		EXPENDED		JOB ORDER NUMBER	BALANCE	
DATE	AMOUNT	DATE	AMOUNT		DATE	AMOUNT
1/15/-	5,000 gal				1/15/-	5,000 gal
		1/15/-	1,000 gal	153-70	1/15/-	4,000 gal
		1/16/-	1,500 gal	"	1/16/-	2,500 gal
		1/19/-	1,000 gal	"	1/19/-	1,500 gal

65.10

Figure 8-6.—Page from a materials expended record.

prior to authorizing the license holder to operate government-owned or rented equipment.

LICENSE EXPIRATION AND RENEWAL

License renewal is dependent upon the licensing examiner's determination only, provided the renewal date is prior to the present license expiration date. The examiner must determine that the operator still meets all requirements for the license being renewed. When any doubt exists, an operator will be reexamined. Operators whose licenses have expired will be reexamined in the same manner as a new applicant. Licenses which expire while personnel are assigned to a combat zone will automatically be extended until return to a noncombat area.

LICENSING PROGRAM

A licensing program is a screening process by which the examiner will determine each applicant's qualifications for obtaining an operator's license. A properly administered program also determines the amount of training each applicant requires. The physical and mental qualities required of competent operators are outlined in chapter 930 of the *Federal Personnel Manual* and chapter 3 of the P-404.

Applicants may be disqualified for physical defects or emotional instability. Justification for disqualification may be derived from interviews, the applicant's medical and personnel records, medical examination, accident reports involving the applicant, and/or specialized clinical test. Such tests should include, but are not limited to, depth perception, brake reaction time, field of vision, and manual dexterity. Local authorities may impose additional requirements for the selection, training, or testing of operators, but these additional requirements must not conflict with provisions of the P-300 or P-404. The license examiner should maintain, under lock and key, an individual jacket for each applicant and operator. These jackets are maintained to provide information on the types of equipment that the operator is qualified to operate, background and experience, examination findings, special requirements, performance record, driver awards, traffic violations, and accident history. All the forms utilized in obtaining a government operator's license become part of these permanent records.

EQUIPMENT STATUS BOARD

CODE	U.S.N.	TYPE	LOCATION	STATUS	REMARKS
0063	91-02546 (5)	BUS 37 PASS. 4 x 2	POOL	2/20/-	SHOP - C PM (5)
0063	91-02547 (2)	BUS 37 PASS. 4 x 2	POOL	2/21/-	PARTS - DEADLINE (2)
0305	94-33530 (1)	TRK ¼ TON UTL 4 x 4	"A" COMPANY CDR		
0313	94-49700 (1)	TRK ½ TON P/U 4 x 2	"UT" PROJECT JOB# 12		
4531	45-15168 (4)	LOADER FRONT-END	POOL		INCOMING (4)
4640	46-12467 (3)	ROLLER 3-WHEEL	POOL		PENDING (3)
4851	48-00312 (1)	TRACTOR CRAWLER	AIRSTRIP JOB# 32		

LEGEND

(1)-BLACK = IN SERVICE-OPERATIONAL
(2)-RED = DEADLINE-PM SCHEDULED
(3)-GREEN = PENDING REPLACEMENT SHIPMENT, EXCESS
(4)-ORANGE = ORDERED IN USN # KNOWN
(5)-BLUE = OPTIONAL-USED BY DEPLOYED BATTALIONS

143.214

Figure 8-7.—Equipment status board.

APPLICATION FORMS

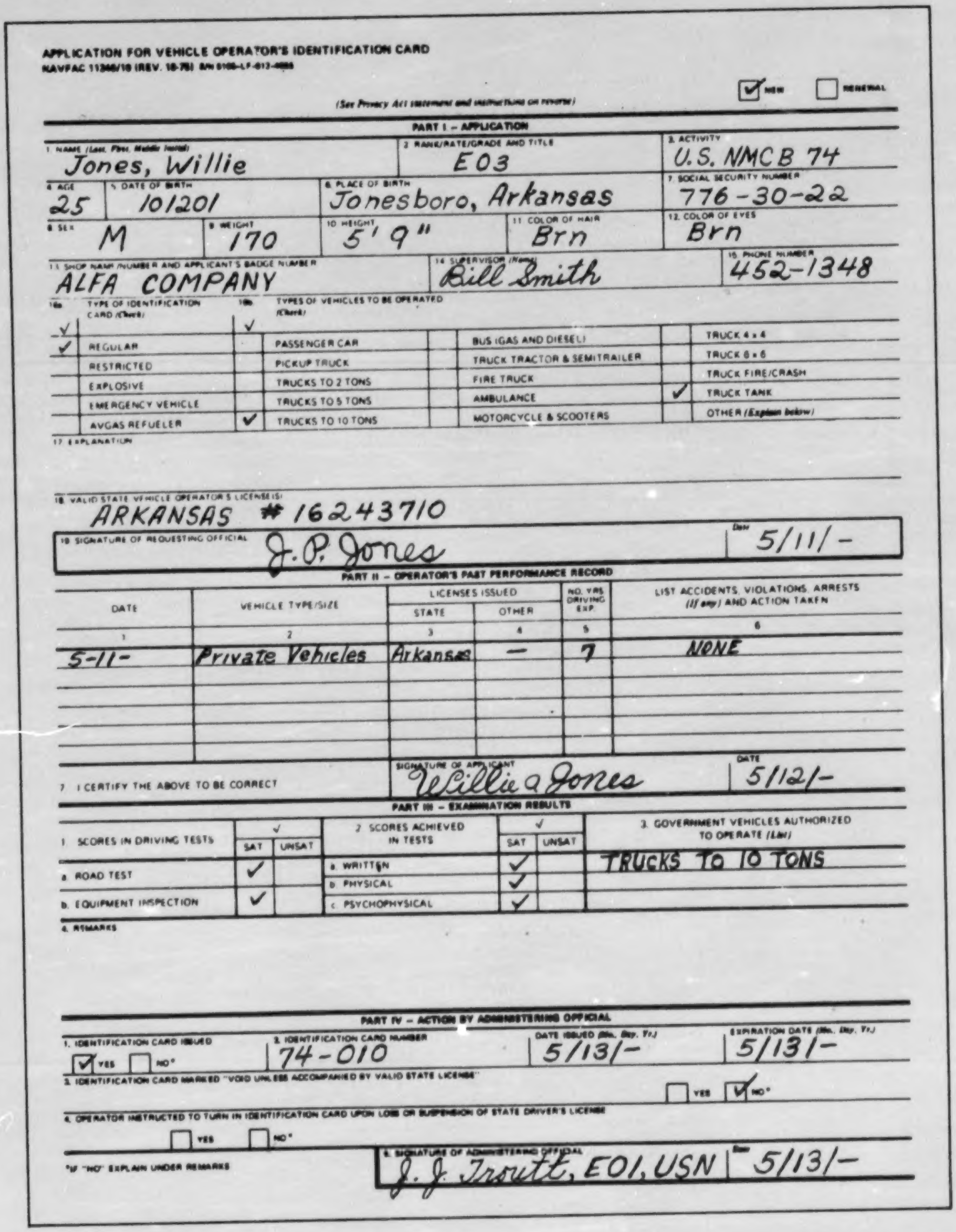
The first step in obtaining an operator's license is to submit an application form to the license examiner. The proper form to use in applying for an automotive or MHE license is an Application for Vehicle Operator's Identification Card, NAVFAC 11240/10 (fig. 8-8 and 8-9). The proper form to use in applying for a license for other types of equipment is Application for Construction Equipment Operators License, NAVFAC Form 11260/1 (fig. 8-10 and 8-11). All application forms will be signed by the requesting official, i.e., the applicant's commanding officer or his designated representative (company commander).

WAIVER OF EXAMINATIONS

Examinations and tests for military personnel applying for a license to operate general-purpose vehicles up to 10,000 GVW will normally be waived, if the applicant possesses a valid state operator's license for the type of vehicles involved.

PHYSICAL FITNESS INQUIRY FORM

Applicants for Standard Form 46 will be required to complete a Standard Form 47, Physical Fitness Inquiry for Motor Vehicle Operators (fig. 8-12). The licensing examiner



APPLICATION FOR VEHICLE OPERATOR'S IDENTIFICATION CARD
NAVFAC 11240/10 (REV. 10-75) S/N 0105-LF-012-[illegible]

☑ NEW ☐ RENEWAL

(See Privacy Act statement and instructions on reverse)

PART I – APPLICATION

1. NAME *(Last, First, Middle Initial)*: Jones, Willie
2. RANK/RATE/GRADE AND TITLE: E03
3. ACTIVITY: U.S. NMCB 74
4. AGE: 25
5. DATE OF BIRTH: 10/201
6. PLACE OF BIRTH: Jonesboro, Arkansas
7. SOCIAL SECURITY NUMBER: 776-30-22
8. SEX: M
9. WEIGHT: 170
10. HEIGHT: 5'9"
11. COLOR OF HAIR: Brn
12. COLOR OF EYES: Brn
13. SHOP NAME/NUMBER AND APPLICANT'S BADGE NUMBER: ALFA COMPANY
14. SUPERVISOR *(Name)*: Bill Smith
15. PHONE NUMBER: 452-1348

16a	TYPE OF IDENTIFICATION CARD *(Check)*	16b	TYPES OF VEHICLES TO BE OPERATED *(Check)*				
✓		✓					
✓	REGULAR		PASSENGER CAR		BUS (GAS AND DIESEL)		TRUCK 4 x 4
	RESTRICTED		PICKUP TRUCK		TRUCK TRACTOR & SEMITRAILER		TRUCK 6 x 6
	EXPLOSIVE		TRUCKS TO 2 TONS		FIRE TRUCK		TRUCK FIRE/CRASH
	EMERGENCY VEHICLE		TRUCKS TO 5 TONS		AMBULANCE	✓	TRUCK TANK
	AVGAS REFUELER	✓	TRUCKS TO 10 TONS		MOTORCYCLE & SCOOTERS		OTHER *(Explain below)*

17. EXPLANATION:

18. VALID STATE VEHICLE OPERATOR'S LICENSE(S): ARKANSAS #16243710

19. SIGNATURE OF REQUESTING OFFICIAL: J. P. Jones — Date: 5/11/-

PART II – OPERATOR'S PAST PERFORMANCE RECORD

DATE	VEHICLE TYPE/SIZE	LICENSES ISSUED		NO. YRS DRIVING EXP.	LIST ACCIDENTS, VIOLATIONS, ARRESTS *(If any)* AND ACTION TAKEN
		STATE	OTHER		
1	2	3	4	5	6
5-11-	Private Vehicles	Arkansas	—	7	NONE

7. I CERTIFY THE ABOVE TO BE CORRECT — SIGNATURE OF APPLICANT: Willie a Jones — DATE: 5/12/-

PART III – EXAMINATION RESULTS

1. SCORES IN DRIVING TESTS	✓		2. SCORES ACHIEVED IN TESTS	✓		3. GOVERNMENT VEHICLES AUTHORIZED TO OPERATE *(List)*
	SAT	UNSAT		SAT	UNSAT	
a. ROAD TEST	✓		a. WRITTEN	✓		TRUCKS TO 10 TONS
			b. PHYSICAL	✓		
b. EQUIPMENT INSPECTION	✓		c. PSYCHOPHYSICAL	✓		

4. REMARKS:

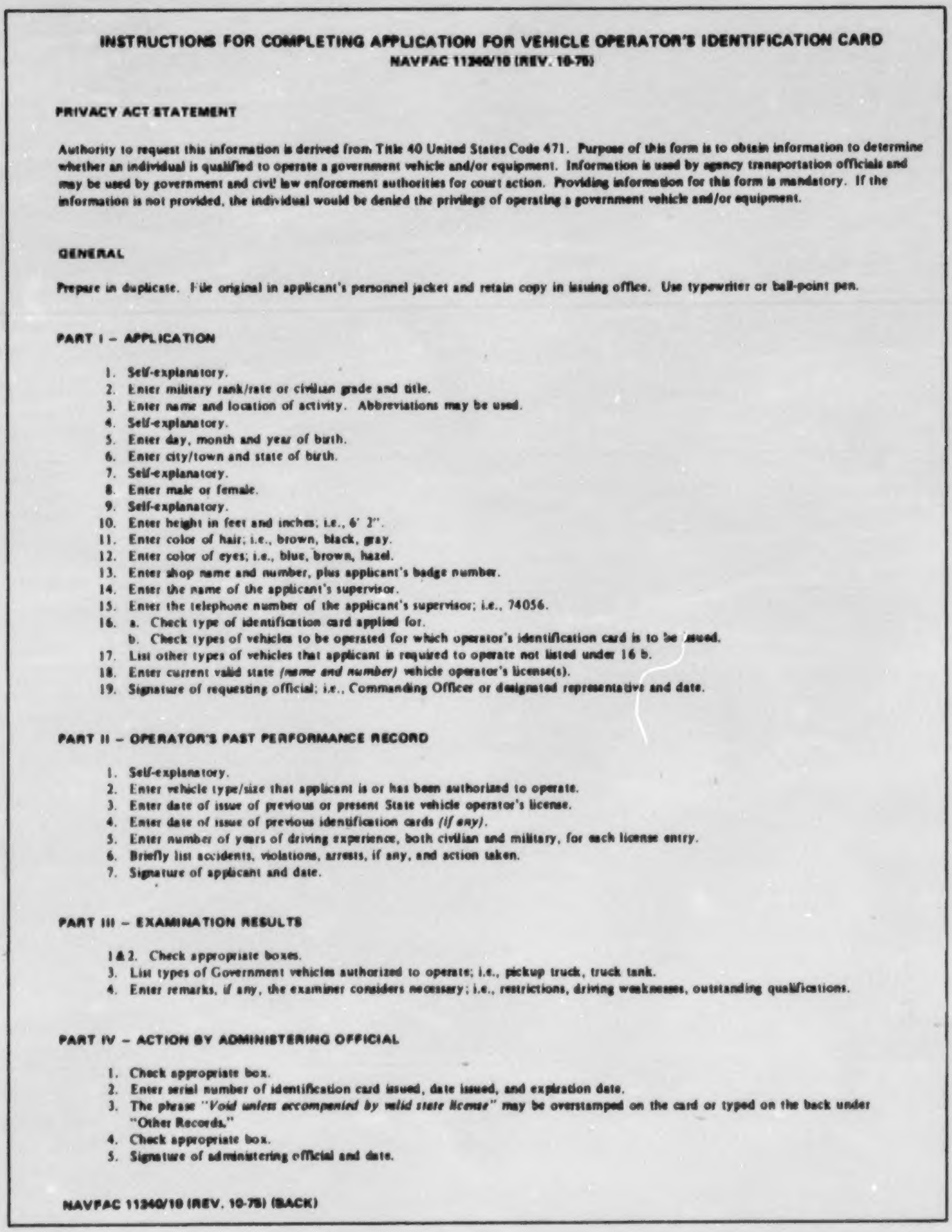
PART IV – ACTION BY ADMINISTERING OFFICIAL

1. IDENTIFICATION CARD ISSUED: ☑ YES ☐ NO*
2. IDENTIFICATION CARD NUMBER: 74-010
DATE ISSUED *(Mo. Day. Yr.)*: 5/13/-
EXPIRATION DATE *(Mo. Day. Yr.)*: 5/13/-
3. IDENTIFICATION CARD MARKED "VOID UNLESS ACCOMPANIED BY VALID STATE LICENSE": ☐ YES ☑ NO*
4. OPERATOR INSTRUCTED TO TURN IN IDENTIFICATION CARD UPON LOSS OR SUSPENSION OF STATE DRIVER'S LICENSE: ☐ YES ☐ NO*
5. SIGNATURE OF ADMINISTERING OFFICIAL: J. J. Troutt, EO1, USN — Date: 5/13/-

*IF "NO" EXPLAIN UNDER REMARKS

143.296

Figure 8-8.—Application for Vehicle Operator's Identification Card, NAVFAC 11240/10 (front).



INSTRUCTIONS FOR COMPLETING APPLICATION FOR VEHICLE OPERATOR'S IDENTIFICATION CARD
NAVFAC 11240/10 (REV. 10-75)

PRIVACY ACT STATEMENT

Authority to request this information is derived from Title 40 United States Code 471. Purpose of this form is to obtain information to determine whether an individual is qualified to operate a government vehicle and/or equipment. Information is used by agency transportation officials and may be used by government and civil law enforcement authorities for court action. Providing information for this form is mandatory. If the information is not provided, the individual would be denied the privilege of operating a government vehicle and/or equipment.

GENERAL

Prepare in duplicate. File original in applicant's personnel jacket and retain copy in issuing office. Use typewriter or ball-point pen.

PART I – APPLICATION

1. Self-explanatory.
2. Enter military rank/rate or civilian grade and title.
3. Enter name and location of activity. Abbreviations may be used.
4. Self-explanatory.
5. Enter day, month and year of birth.
6. Enter city/town and state of birth.
7. Self-explanatory.
8. Enter male or female.
9. Self-explanatory.
10. Enter height in feet and inches; i.e., 6' 2".
11. Enter color of hair; i.e., brown, black, gray.
12. Enter color of eyes; i.e., blue, brown, hazel.
13. Enter shop name and number, plus applicant's badge number.
14. Enter the name of the applicant's supervisor.
15. Enter the telephone number of the applicant's supervisor; i.e., 74056.
16. a. Check type of identification card applied for.
    b. Check types of vehicles to be operated for which operator's identification card is to be issued.
17. List other types of vehicles that applicant is required to operate not listed under 16 b.
18. Enter current valid state *(name and number)* vehicle operator's license(s).
19. Signature of requesting official; *i.e.*, Commanding Officer or designated representative and date.

PART II – OPERATOR'S PAST PERFORMANCE RECORD

1. Self-explanatory.
2. Enter vehicle type/size that applicant is or has been authorized to operate.
3. Enter date of issue of previous or present State vehicle operator's license.
4. Enter date of issue of previous identification cards *(if any)*.
5. Enter number of years of driving experience, both civilian and military, for each license entry.
6. Briefly list accidents, violations, arrests, if any, and action taken.
7. Signature of applicant and date.

PART III – EXAMINATION RESULTS

1 & 2. Check appropriate boxes.
3. List types of Government vehicles authorized to operate; i.e., pickup truck, truck tank.
4. Enter remarks, if any, the examiner considers necessary; i.e., restrictions, driving weaknesses, outstanding qualifications.

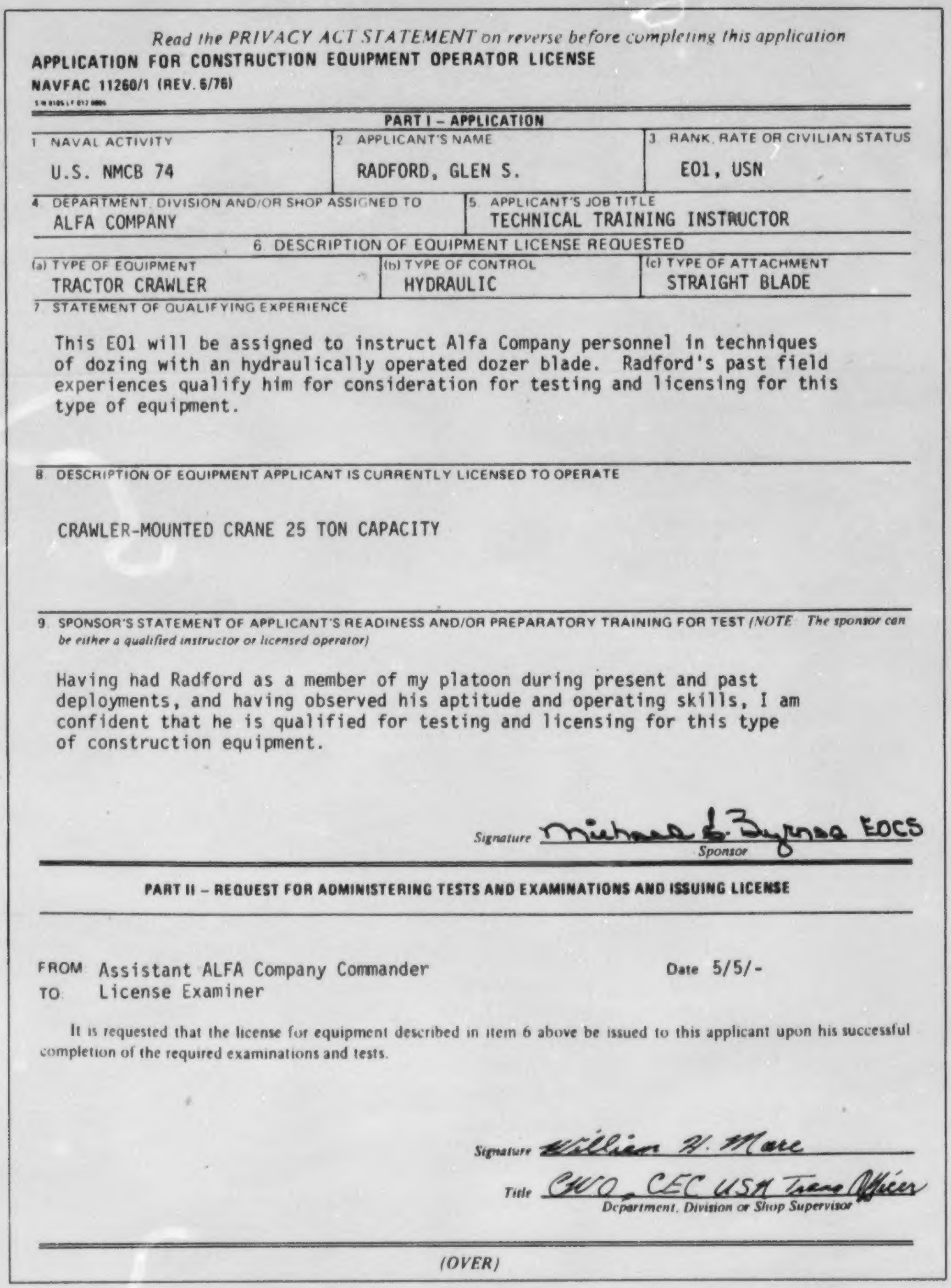
PART IV – ACTION BY ADMINISTERING OFFICIAL

1. Check appropriate box.
2. Enter serial number of identification card issued, date issued, and expiration date.
3. The phrase *"Void unless accompanied by valid state license"* may be overstamped on the card or typed on the back under "Other Records."
4. Check appropriate box.
5. Signature of administering official and date.

NAVFAC 11240/10 (REV. 10-75) (BACK)

143.296

Figure 8-9.–Application for Vehicle Operator's Identification Card, NAVFAC 11240/10 (back).



Read the PRIVACY ACT STATEMENT on reverse before completing this application

APPLICATION FOR CONSTRUCTION EQUIPMENT OPERATOR LICENSE

NAVFAC 11260/1 (REV. 5/76)

PART I – APPLICATION

1. NAVAL ACTIVITY U.S. NMCB 74	2. APPLICANT'S NAME RADFORD, GLEN S.	3. RANK, RATE OR CIVILIAN STATUS EO1, USN

4. DEPARTMENT, DIVISION AND/OR SHOP ASSIGNED TO ALFA COMPANY	5. APPLICANT'S JOB TITLE TECHNICAL TRAINING INSTRUCTOR

6. DESCRIPTION OF EQUIPMENT LICENSE REQUESTED

(a) TYPE OF EQUIPMENT TRACTOR CRAWLER	(b) TYPE OF CONTROL HYDRAULIC	(c) TYPE OF ATTACHMENT STRAIGHT BLADE

7. STATEMENT OF QUALIFYING EXPERIENCE

This EO1 will be assigned to instruct Alfa Company personnel in techniques of dozing with an hydraulically operated dozer blade. Radford's past field experiences qualify him for consideration for testing and licensing for this type of equipment.

8. DESCRIPTION OF EQUIPMENT APPLICANT IS CURRENTLY LICENSED TO OPERATE

CRAWLER-MOUNTED CRANE 25 TON CAPACITY

9. SPONSOR'S STATEMENT OF APPLICANT'S READINESS AND/OR PREPARATORY TRAINING FOR TEST *(NOTE: The sponsor can be either a qualified instructor or licensed operator)*

Having had Radford as a member of my platoon during present and past deployments, and having observed his aptitude and operating skills, I am confident that he is qualified for testing and licensing for this type of construction equipment.

Signature Michael L. Byrnes EOCS
Sponsor

PART II – REQUEST FOR ADMINISTERING TESTS AND EXAMINATIONS AND ISSUING LICENSE

FROM: Assistant ALFA Company Commander — Date 5/5/-
TO: License Examiner

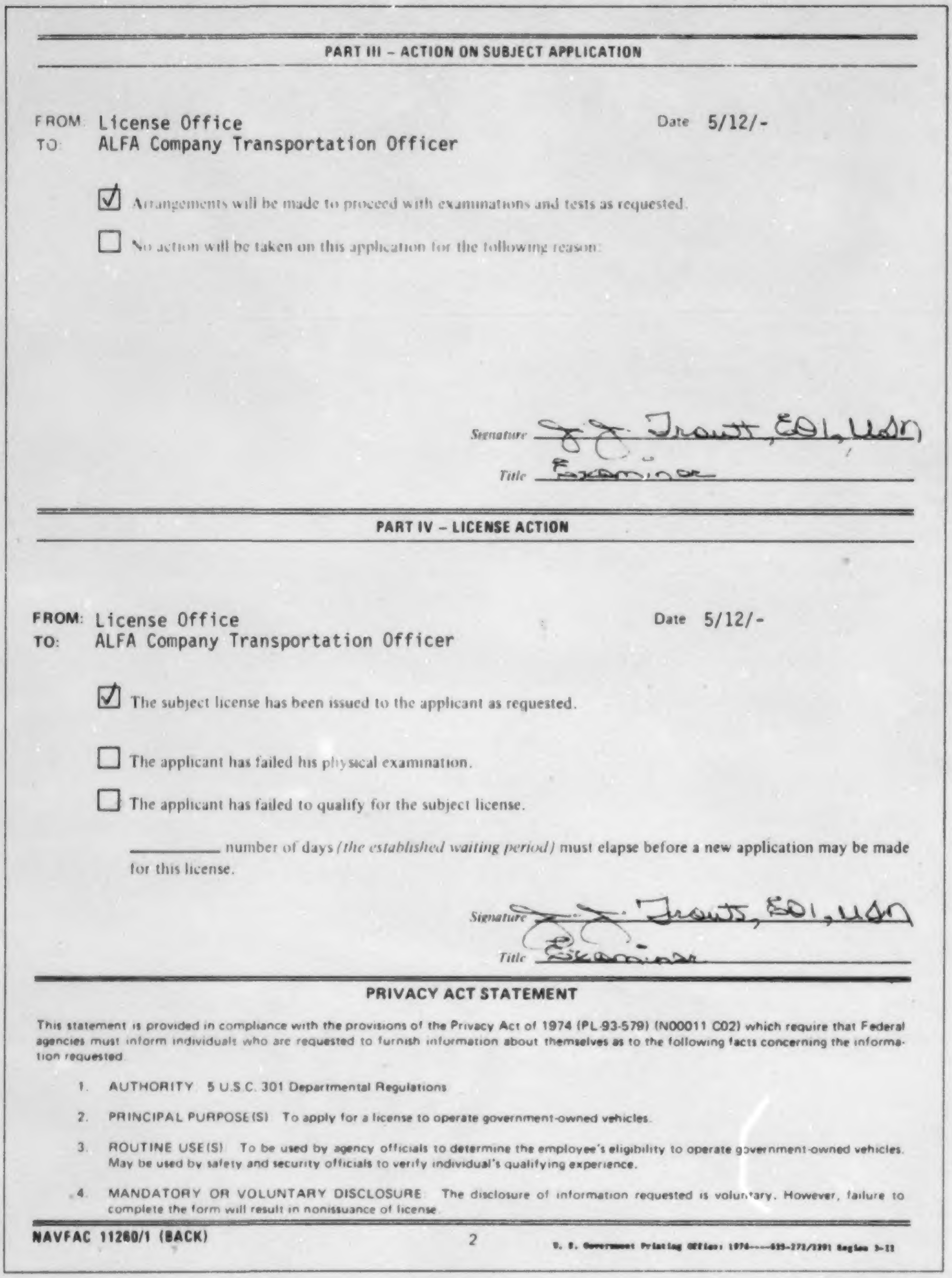
It is requested that the license for equipment described in item 6 above be issued to this applicant upon his successful completion of the required examinations and tests.

Signature William H. Mare
Title CWO, CEC USN Trans Officer
Department, Division or Shop Supervisor

(OVER)

143.223

Figure 8-10.—Application for Construction Equipment Operator License, NAVFAC 11260/1 (front).



PART III – ACTION ON SUBJECT APPLICATION

FROM: License Office Date 5/12/-
TO: ALFA Company Transportation Officer

☑ Arrangements will be made to proceed with examinations and tests as requested.

☐ No action will be taken on this application for the following reason:

Signature J. J. Troutt, EO1, USN
Title Examiner

PART IV – LICENSE ACTION

FROM: License Office Date 5/12/-
TO: ALFA Company Transportation Officer

☑ The subject license has been issued to the applicant as requested.

☐ The applicant has failed his physical examination.

☐ The applicant has failed to qualify for the subject license.

__________ number of days *(the established waiting period)* must elapse before a new application may be made for this license.

Signature J. J. Troutt, EO1, USN
Title Examiner

PRIVACY ACT STATEMENT

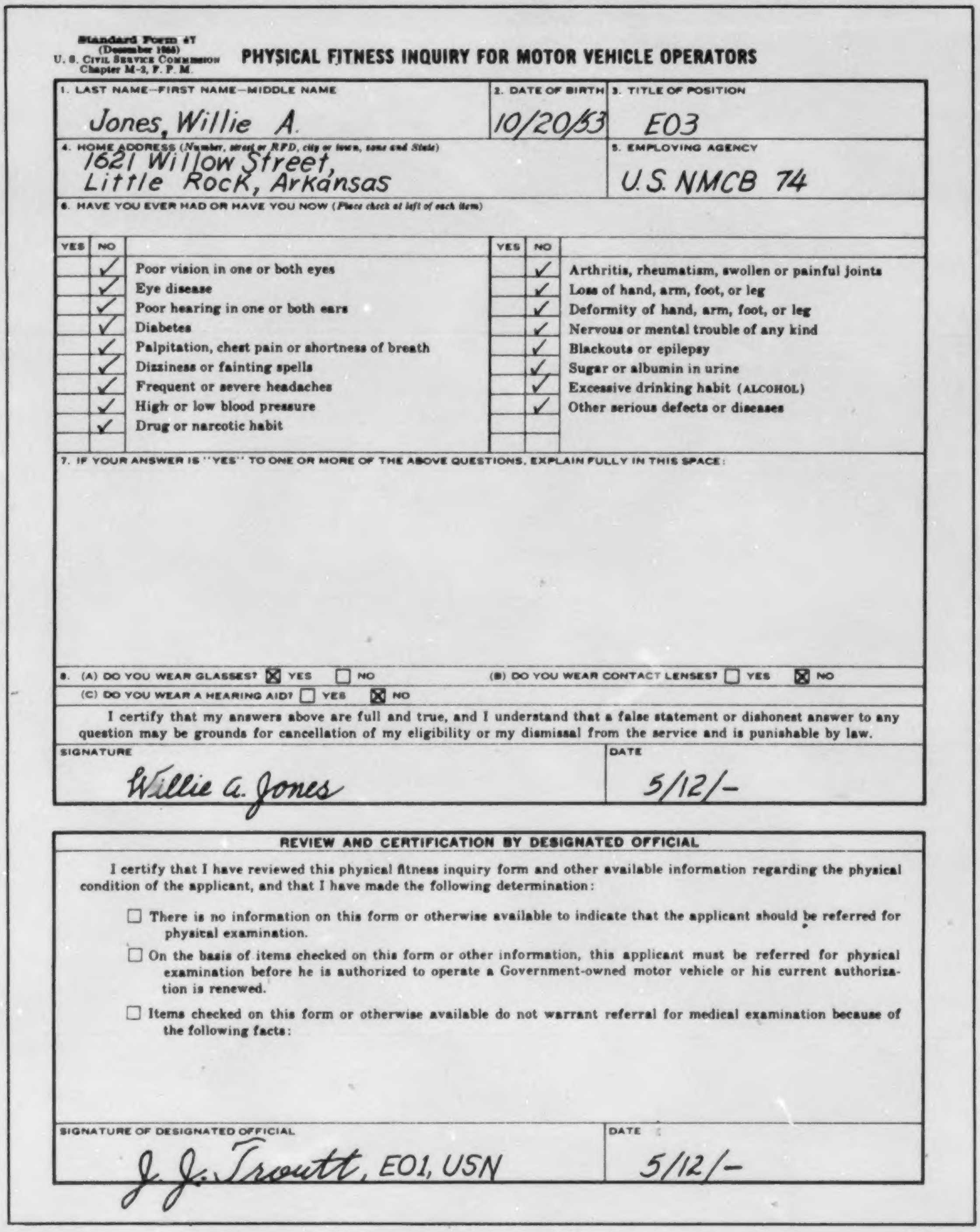
This statement is provided in compliance with the provisions of the Privacy Act of 1974 (PL 93-579) (N00011 C02) which require that Federal agencies must inform individuals who are requested to furnish information about themselves as to the following facts concerning the information requested.

1. AUTHORITY 5 U.S.C. 301 Departmental Regulations
2. PRINCIPAL PURPOSE(S) To apply for a license to operate government-owned vehicles.
3. ROUTINE USE(S) To be used by agency officials to determine the employee's eligibility to operate government-owned vehicles. May be used by safety and security officials to verify individual's qualifying experience.
4. MANDATORY OR VOLUNTARY DISCLOSURE The disclosure of information requested is voluntary. However, failure to complete the form will result in nonissuance of license.

NAVFAC 11260/1 (BACK) 2 U. S. Government Printing Office: 1974----[illegible]

143.223

Figure 8-11.–Application for Construction Equipment Operator License, NAVFAC 11260/1 (back).



Standard Form 47
(December 1966)
U. S. Civil Service Commission
Chapter M-3, F. P. M.

PHYSICAL FITNESS INQUIRY FOR MOTOR VEHICLE OPERATORS

1. LAST NAME—FIRST NAME—MIDDLE NAME: Jones, Willie A.

2. DATE OF BIRTH: 10/20/53

3. TITLE OF POSITION: E03

4. HOME ADDRESS (Number, street or RFD, city or town, zone and State):
1621 Willow Street,
Little Rock, Arkansas

5. EMPLOYING AGENCY: U.S. NMCB 74

6. HAVE YOU EVER HAD OR HAVE YOU NOW (Place check at left of each item)

YES	NO		YES	NO	
	✓	Poor vision in one or both eyes		✓	Arthritis, rheumatism, swollen or painful joints
	✓	Eye disease		✓	Loss of hand, arm, foot, or leg
	✓	Poor hearing in one or both ears		✓	Deformity of hand, arm, foot, or leg
	✓	Diabetes		✓	Nervous or mental trouble of any kind
	✓	Palpitation, chest pain or shortness of breath		✓	Blackouts or epilepsy
	✓	Dizziness or fainting spells		✓	Sugar or albumin in urine
	✓	Frequent or severe headaches		✓	Excessive drinking habit (ALCOHOL)
	✓	High or low blood pressure		✓	Other serious defects or diseases
	✓	Drug or narcotic habit			

7. IF YOUR ANSWER IS "YES" TO ONE OR MORE OF THE ABOVE QUESTIONS, EXPLAIN FULLY IN THIS SPACE:

8. (A) DO YOU WEAR GLASSES? ☒ YES ☐ NO (B) DO YOU WEAR CONTACT LENSES? ☐ YES ☒ NO
(C) DO YOU WEAR A HEARING AID? ☐ YES ☒ NO

I certify that my answers above are full and true, and I understand that a false statement or dishonest answer to any question may be grounds for cancellation of my eligibility or my dismissal from the service and is punishable by law.

SIGNATURE: Willie A. Jones

DATE: 5/12/-

REVIEW AND CERTIFICATION BY DESIGNATED OFFICIAL

I certify that I have reviewed this physical fitness inquiry form and other available information regarding the physical condition of the applicant, and that I have made the following determination:

☐ There is no information on this form or otherwise available to indicate that the applicant should be referred for physical examination.

☐ On the basis of items checked on this form or other information, this applicant must be referred for physical examination before he is authorized to operate a Government-owned motor vehicle or his current authorization is renewed.

☐ Items checked on this form or otherwise available do not warrant referral for medical examination because of the following facts:

SIGNATURE OF DESIGNATED OFFICIAL: J. J. Troutt, EO1, USN

DATE: 5/12/-

143.217

Figure 8-12.—Physical Fitness Inquiry for Motor Vehicle Operators, Standard Form 47.

will review and evaluate this physical fitness inquiry form and other available information regarding the physical condition of the applicant and make a determination if a physical examination is required. Operators must have no physical defects or emotional instability which render them a hazard to themselves or others. Physical examinations are required for operators assigned to transport explosives. The Medical Department conducts all physical examinations referred to by the license examiner. The results are recorded in the appropriate portion of the application form.

WRITTEN TESTS

Applicants must pass a written examination to determine their degree of preparedness prior to administering the performance qualification tests. The tests will be based on traffic laws/regulations, accident reporting procedures, operator's maintenance responsibilities, safe driving practices, and characteristics and limitations of the types of equipment for which the test is being given. At least two written tests will be developed for each type of equipment. Numerous sample written tests for construction and weight-handling equipment are contained in NAVFAC P-306, *Testing and Licensing of Construction Equipment Operators*.

PERFORMANCE QUALIFICATION TESTS

Applicants who pass the written test will then be given a Performance Qualification Test. This test will enable a qualified examiner to evaluate the demonstrable operating skills of the applicant. The examiner must terminate any performance test he believes to be hazardous. Some reasons for ending a test are obvious: lack of skill, undue nervousness, speeding, inattentiveness, etc. Personnel failing to qualify for a license will not be reexamined until after further training or instruction. The specific reason for failure will be noted on the application which is then filed in the applicant's jacket.

Automotive Tests

Applicants for an SF-46 must first pass a locally devised driver skill test before being given a road test to determine their reactions under varying traffic conditions. The road test shall be administered in the greatest capacity vehicle for which the license is to be issued. A locally devised checklist will be utilized in evaluating the road test.

Materials-Handling Equipment (MHE) Tests

Applicants for the MHE license will be operationally tested and scored as prescribed in NAVSUP P-284, *Storage Materials Handling*. This publication also contains sample test questions.

Construction Type Tests

Applicants for a NAVFAC 11260/2 must be familiar with the standard Navy hand signals prior to taking a performance qualification test. Some of the hand signals commonly used are shown in appendix III. There is a wide variety of construction and weight-handling equipment in use by the Navy for which it is not practical to devise and administer standard Navy-wide performance qualifications tests. The local examiner must prepare operational tests as required. Numerous sample operational tests are contained in the NAVFAC P-306.

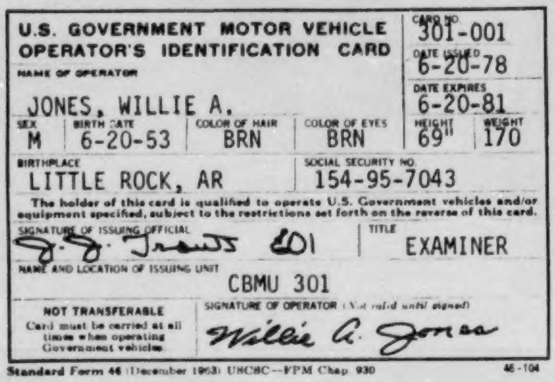
LICENSING FORMS

After an applicant satisfactorily completes all the required tests, the examiner will issue a license which shows each type vehicle the license holder is authorized to operate, plus any restrictions imposed on the license.

Standard Form 46

Standard Form 46 (fig. 8-13 and 8-14) is the proper license for automotive motor vehicles and materials-handling equipment. To be properly completed and valid, an SF-46 must have the following entries:

1. Card Number: A two-part sequential number which is the actual license number. The first part of the number is the activity number or unit designation of the original license issuing activity. The second part of the number is the



U.S. GOVERNMENT MOTOR VEHICLE OPERATOR'S IDENTIFICATION CARD

CARD NO. 301-001

DATE ISSUED 6-20-78

NAME OF OPERATOR JONES, WILLIE A.

DATE EXPIRES 6-20-81

SEX	BIRTH DATE	COLOR OF HAIR	COLOR OF EYES	HEIGHT	WEIGHT
M	6-20-53	BRN	BRN	69"	170

BIRTHPLACE LITTLE ROCK, AR

SOCIAL SECURITY NO. 154-95-7043

The holder of this card is qualified to operate U.S. Government vehicles and/or equipment specified, subject to the restrictions set forth on the reverse of this card.

SIGNATURE OF ISSUING OFFICIAL J. J. Traut EO1

TITLE EXAMINER

NAME AND LOCATION OF ISSUING UNIT CBMU 301

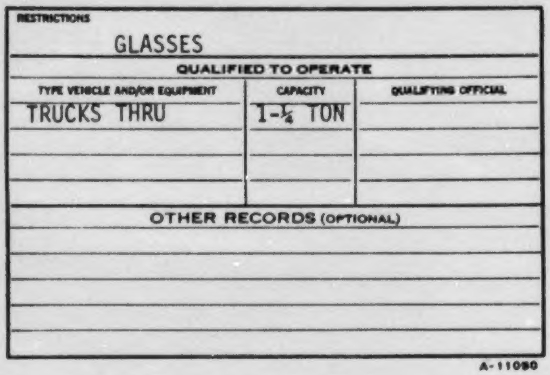
NOT TRANSFERABLE Card must be carried at all times when operating Government vehicles

SIGNATURE OF OPERATOR (Not valid until signed) Willie A. Jones

Standard Form 46 (December 1963) USCSC--FPM Chap. 930 46-104

115.45

Figure 8-13.—U.S. Government Motor Vehicle Operator's Identification Card, Standard Form 46 (front).



RESTRICTIONS GLASSES

QUALIFIED TO OPERATE

TYPE VEHICLE AND/OR EQUIPMENT	CAPACITY	QUALIFYING OFFICIAL
TRUCKS THRU	1-¼ TON	

OTHER RECORDS (OPTIONAL)

A-11090

115.45

Figure 8-14.—U.S. Government Motor Vehicle Operator's Identification Card, Standard Form 46(back).

appropriate sequential number in order of issue. Example: The first license issued by CBMU 301 would be numbered 301-001.

2. Restrictions: Physical limitations and restrictions. Typical notations are glasses, daytime, hearing aid, learner, etc.

3. Types of Vehicle and/or Equipment: Description of equipment the operator is qualified to operate. Each separate item does not have to be listed; utilize notations like trucks through 1-1/4 ton, tractor and trailer through 10 ton, etc.

4. Capacity: See item number 3.

5. Qualifying Official: Signature of examiner.

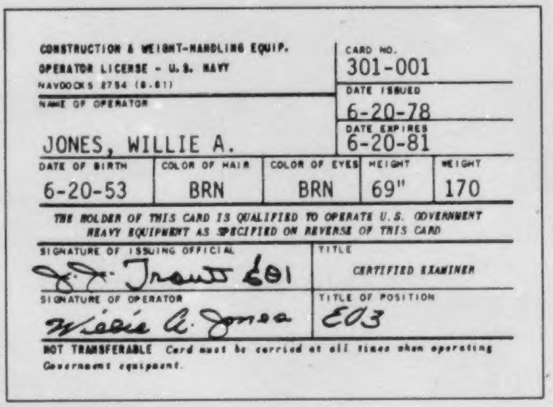
6. Other Records: To be utilized for types of licenses that require specific notation, i.e., ambulance, fire truck, ammunition and explosive license, avgas refueler, etc. Can be utilized as a continuation for items 3 and 4.

The SF-46 is valid for 3 years and may be renewed for additional periods of 3 years each. Expiration dates shall be the operator's birth date.

NAVFAC Form 11260/2

NAVFAC Form 11260/2, Construction Equipment Operator License, (fig. 8-15 and 8-16) is the proper license for operating construction equipment. To be properly completed and valid, a NAVFAC 11260/2 must have the following entries:

1. Card Number: A two-part sequential number which is the actual license number. The



CONSTRUCTION & WEIGHT-HANDLING EQUIP.
OPERATOR LICENSE - U.S. NAVY
NAVDOCKS 2754 (8-61)

CARD NO. 301-001

DATE ISSUED 6-20-78

NAME OF OPERATOR JONES, WILLIE A.

DATE EXPIRES 6-20-81

DATE OF BIRTH	COLOR OF HAIR	COLOR OF EYES	HEIGHT	WEIGHT
6-20-53	BRN	BRN	69"	170

THE HOLDER OF THIS CARD IS QUALIFIED TO OPERATE U.S. GOVERNMENT HEAVY EQUIPMENT AS SPECIFIED ON REVERSE OF THIS CARD

SIGNATURE OF ISSUING OFFICIAL J. J. Traut EO1

TITLE CERTIFIED EXAMINER

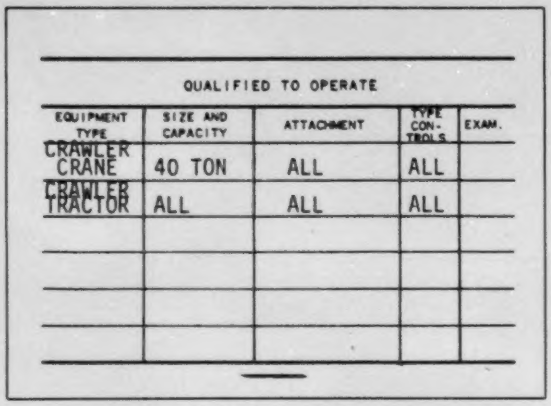
SIGNATURE OF OPERATOR Willie A. Jones

TITLE OF POSITION EO3

NOT TRANSFERABLE Card must be carried at all times when operating Government equipment.

143.222

Figure 8-15.—Construction Equipment Operator License, NAVFAC Form 11260/2 (front).



QUALIFIED TO OPERATE

EQUIPMENT TYPE	SIZE AND CAPACITY	ATTACHMENT	TYPE CON-TROLS	EXAM.
CRAWLER CRANE	40 TON	ALL	ALL	
CRAWLER TRACTOR	ALL	ALL	ALL	

143.222

Figure 8-16.—Construction Equipment Operator License, NAVFAC Form 11260/2 (back).

first part of the number is the activity number or unit designation of the original license issuing activity. The second part of the number is the appropriate sequential number in order of issue. Example: The first license issued by CBMU 301 would be numbered 301-001.

2. Date Issued: Abbreviated entries of the issuing date, month, and year.
3. Date Expires: Abbreviated entries of the expiration date, month, and year. The NAVFAC 11260/2 is valid for 2 years figured from the operator's birth date.
4. Name of Operator: The operator's name, as contained in official personnel records. The use of identification numbers is optional.
5. Equipment Type: Description of the basic units the operator is qualified to operate. Typical notations are crawler crane, crawler tractor, front-end loader, etc.

6. Attachment: Description of the attachments the operator is qualified to operate. Typical notations are: shovel front, backhoe, dragline, all attachments, etc. Can also be utilized to denote gas- or diesel-powered.

7. Type Controls: On that equipment where control types are variable, enter Hydraulic (H), Electrical (E), and/or Mechanical (M) as appropriate.

The NAVFAC 11260/2 is valid for 2 years and may be renewed for additional periods of 2 years each. Expiration dates shall be the operator's birth date in odd or even years, consistent with the operator's year of birth; for example, if the birth date is 20 June 1940, the expiration dates will be 20 June 1980, 20 June 1982, and so on, every 2 years.

The license examiner will maintain a tickler file of each operator's license expiration date. Renewal action should start approximately 90 days before the expiration date. The examiner must maintain an additional History Record for construction operators NAVFAC 11260/3 (fig. 8-17). Upon transfer, this jacket, which contains all relevant forms with supporting data, will be forwarded with the individual's personnel service record.

LICENSE UPGRADING

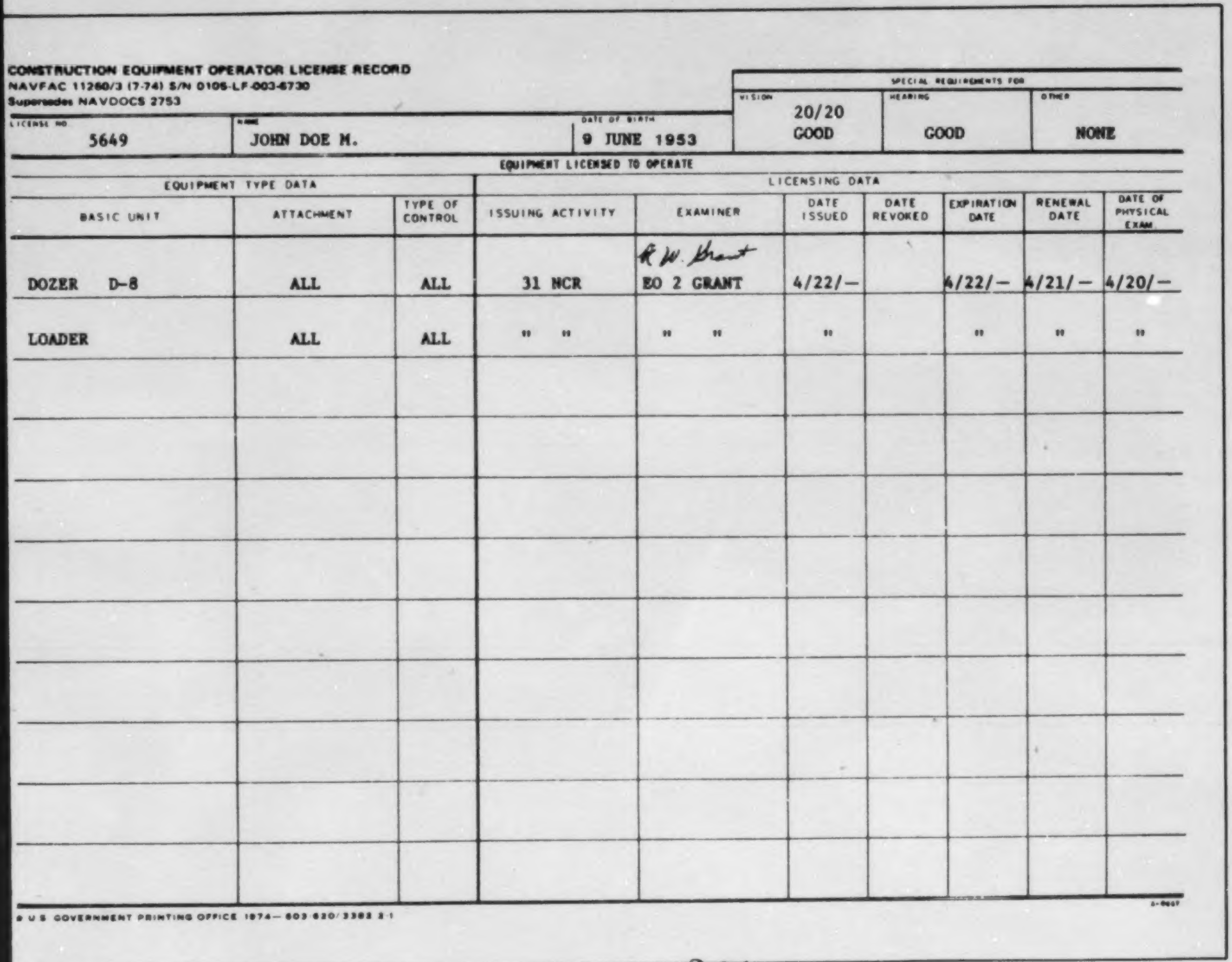
Applications for upgrading a license to larger or different types of equipment will be submitted in the same manner as original requests. The only test normally required for upgrading a license is an operator qualifying test for the type and capacity equipment the license is being upgraded to. The license examiner will sign the upgrade entry on the SF-46 or the NAVFAC 11260/2. After upgrading and completion, the application will be forwarded for inclusion in the applicant's personnel service records.

LOST OR MUTILATED LICENSES

Lost, destroyed or mutilated licenses may be replaced upon verification of the original license issued. This verification can be accomplished by referring to the License Application Form filed in the appropriate personnel service record or from the license examiner's records.

LICENSE CANCELLATION

When a person leaves the service all government licenses are cancelled. Personnel may retain the license provided it is stamped "Cancelled Due to Separation" across the front, initialed, and dated by the examiner.



CONSTRUCTION EQUIPMENT OPERATOR LICENSE RECORD
NAVFAC 11260/3 (7-74) S/N 0105-LF-003-6730
Supersedes NAVDOCS 2753

LICENSE NO.	NAME	DATE OF BIRTH	SPECIAL REQUIREMENTS FOR VISION	SPECIAL REQUIREMENTS FOR HEARING	SPECIAL REQUIREMENTS FOR OTHER
5649	JOHN DOE M.	9 JUNE 1953	20/20 GOOD	GOOD	NONE

EQUIPMENT LICENSED TO OPERATE

EQUIPMENT TYPE DATA			LICENSING DATA						
BASIC UNIT	ATTACHMENT	TYPE OF CONTROL	ISSUING ACTIVITY	EXAMINER	DATE ISSUED	DATE REVOKED	EXPIRATION DATE	RENEWAL DATE	DATE OF PHYSICAL EXAM
DOZER D-8	ALL	ALL	31 NCR	R. W. Grant EO 2 GRANT	4/22/—		4/22/—	4/21/—	4/20/—
LOADER	ALL	ALL	" "	" "	"		"	"	"

☆ U.S. GOVERNMENT PRINTING OFFICE 1974—603-620/3382 2-1

143.225

Figure 8-17.—Construction Equipment Operator License Record, NAVFAC 11260/3.

LICENSE SUSPENSION AND REVOCATION

Commanding officers, officers in charge, and equipment officers may revoke or suspend an operator's license at any time for cause. All revoked or suspended licenses should be returned to the license office without delay. Supporting justification and records for license suspensions and revocation should be kept in the Equipment Operator's license file. When a construction operator's license is revoked, the examiner should make a notation in the "Date Revoked" column of the NAVFAC Form 11260/3, Construction Equipment Operator License Record (fig. 8-17). Revoked licenses will not be restored until the operator is fully qualified through reevaluation and reexamination. Requests for reexamination of operators whose licenses have been suspended or revoked should specifically outline the incidents leading to the suspension or revocation in order that special training emphasis can be placed on that portion of the reexamination. Licenses are usually suspended for a designated time period with no further testing required for reinstatement.

TRAINING PROGRAM

Poor equipment operating practices and habits cause accidents and premature equipment breakdowns. An effective training program, conducted prior to issuing and renewing licenses, will substantially reduce these poor practices and habits. In addition to the license examiner, this training must be supervised by the Equipment Officer, Safety Officer, the applicant's supervisor, and other qualified operators.

TRAINING LICENSE

Before an applicant can receive a training license, his supervisor must submit a written application to the license examiner. This application must specify what equipment the applicant is to be trained on, and who the qualified supervisor will be. After meeting all required physical and mental qualifications, training applicants can be issued a temporary license with the word "Learner" stamped on the face. The training license will have a specified expiration date which normally should not exceed 30 days. A training license is only valid when the trainee is accompanied by a qualified instructor and/or when the trainee is utilizing Navy equipment in a controlled training environment. Training licenses are not required to operate Navy equipment as part of formalized training programs, such as those given at Naval Construction Training Centers (NCTC's).

COURSE OF INSTRUCTION

In addition to learning how to operate equipment, a trainee is required to study a course of instruction. This locally prepared course shall include, but need not be limited to, the following subjects:

1. Fundamentals of vehicle operation, functions and proper use of major assemblies and attachments, equipment limitations.
2. Operator responsibilities; before, during and after operation maintenance.
3. Safety precautions and accident prevention through safe driving practices.
4. Traffic laws, rules and regulations; hand signals, traffic signs, signals and markings.
5. Accident reporting procedures, and other forms and reports that an operator is responsible for completing.

RESTRICTIONS

Certain restrictions on the use of Navy vehicles have been established as a means of control. Failure to observe these restrictions can result in a penalty. Most restrictions on the use of Navy vehicles fall under the limiting phrase "For Official Use Only," and are found in various Navy directives and public laws. "Official use" is defined as "the employment, or authorization of employment, of such Navy motor vehicles as may be required for the discharge of performance of an official Navy duty, function, or service." Unauthorized use exposes military personnel to trial by court martial, under article 121 of the Uniform Code of Military Justice.

If your operators drive government vehicles on public streets and highways, make sure they know and understand all state and local traffic laws and regulations pertaining to the operation of motor vehicles. When on deployment, make sure you have a copy of the local traffic regulations available.

ENVIRONMENTAL POLLUTION CONTROL

Environmental pollution is that condition which results from the presence of chemical, physical, or biological agents in the air, water, or soil which alter the natural environment. This causes an adverse effect on human health or comfort, fish and wildlife, other aquatic resources and plant life, and structures and equipment to the extent that economic loss is produced and recreational opportunity is impaired. Pollution can cause nylon hose to disintegrate, masonry to crumble, steel to corrode, and skies to darken. It can also damage vegetation, cause illness, and result in the loss of countless workdays.

AIR POLLUTION

As an EO, you should be aware of the conditions which cause air pollution when operating equipment, and the efforts being made to minimize or correct these conditions.

When incomplete combustion occurs, unburned hydrocarbons and various other constituents in the basic fuel combine chemically to form some visible, noxious, and harmful byproducts which are emitted into the environment. Some of the fuel components and combustion products which have an adverse effect on the air are carbon monoxide, particulate matter, sulfur, oxides, unburned hydrocarbons, nitrogen oxides, and lead.

CONTROLLING AIR POLLUTION

The most effective means you have of controlling air pollution caused by fuel combustion is to maintain well-tuned engines that provide optimum fuel and oxygen mixture and proper timing that results in efficient combustion. Another alternative, not always under you control, is to use only the best grade of fuel available which contains low particulate matter, low water and sulfur content, and other contaminants. Automotive manufacturers now provide systems on engines to return "blowby" (unburned fuel) to the carburetor for combustion, i.e., a pollution control system. Long range research and development is underway in developing systems to remove harmful constituents from engine exhausts, e.g., catalytic filter scrubber systems to remove oxides of sulfur and nitrogen, and others to remove lead.

WATER AND GROUND POLLUTION

In addition to creating a fire hazard, oil and other fuel products pose many possible pollution threats when spilled on the water or ground. Oil products on the ground can infiltrate and contaminate surface water supplies with ground runoff due to rain. Oil products carried into storm or sanitary sewers pose potential explosion hazards. Gasoline seeping into a sewer from a service station created an explosion which demolished several city blocks in a Chicago suburb in the late 1940's.

Oil on the water surface block the oxygen flow from the atmosphere into the water which results in less oxygen in the water for the fish and other aquatic organisms. Fish can be harmed by eating oil or smaller organisms that have eaten the oil. If the fish do not die from the oil coating their gills or from eating the oil, their flesh is tainted and they are no longer suitable for consumption by man. In addition to harming aquatic organisms and contaminating water supplies, oil products foul boats, waterfront structures, beaches, and in general create an unsightly mess along the waterfront.

Of all the oil introduced in the world's waters, spent oils from highway vehicles accounted for 37 percent, or 2 million tons in 1969. This is the largest single source of oil pollution, even greater than tankers (11 percent), other ships (10 percent), offshore oil production (2 percent), refineries and petrochemical plants (6 percent), industrial and all other vehicles (31 percent), and accidental spills (4 percent).

PREVENTIVE MEASURES FOR WATER AND GROUND POLLUTION

During automotive repair, you should provide drip pans and absorbent materials to catch all unavoidable spills. Spilled oil or fuels should never be washed down a drain or sewer, unless an immediate fire hazard exists and an oil-water separator is present in the discharge line. Where spills are expected to occur (gasoline fill stands, etc.), absorbent material can be sprinkled on spilled oil or fuel, placed in a container, and disposed of in a sanitary landfill or other nonpolluting manner.

Spent crankcase oil, filters, and contaminated fuel should be collected and disposed of in a nonpolluting manner. Most naval activities collect and dispose of waste oil periodically through a contractor, by burning in a boiler plant, or reprocessing in an oil reclamation plant. Naval supply fuel farms usually have means to properly dispose of waste oils.

Open vehicle repair or maintenance areas located near watercourses or bodies of water should be landscaped and diked so spilled oil products cannot easily or directly flow into the nearby water.

In addition to preventing oil pollution from vehicle and equipment operation, SEABEES are being considered for use in beach cleanup during major oil spill disasters. The techniques and uses of construction equipment in beach cleanup may be incorporated in training requirements and, in the event of a regional or national disaster from a major oil spill, the new capability can be utilized as required by local Commanders through the SEABEE unit's self-help program or on a national scale. A well-trained SEABEE team could form the nucleus and directing force of a large scale beach cleanup exercise employing a large number of men and equipment.

CHAPTER 9

MISCELLANEOUS CONSTRUCTION EQUIPMENT

This chapter describes principles and techniques of operating and maintaining an aggregate and cement batching plant, concrete transit mixer, slip-form paver, diesel or pneumatic pile hammer, power earth auger, and steam cleaner. Also, information is presented on the optimum payloads, rates, of operation, and safe working practices for weight-handling equipment.

AGGREGATE AND CEMENT BATCHING PLANT

On large jobs the aggregate is stored and weighed out in an aggregate BATCHING PLANT (usually shortened to "batch plant") like the one shown in figure 9-1. A batch plant is, whenever possible, located near and used in conjunction with a CRUSHING AND/OR SCREENING plant. In a crushing and screening plant, stone is crushed into various particle sizes, which are then screened into separate piles. In a screening plant, the aggregate in its natural state, is screened by sizes into separate piles.

The batch plant is usually a portable affair which can be knocked down and moved from site to site. It is set up adjacent to the piles of screened aggregate. The batch plant may include separate hoppers for several sizes of fine and coarse aggregate; it may include one hopper for fine aggregate and another for coarse aggregate; or it may include one or more DIVIDED hoppers, each containing two or more separate compartments for different sizes of aggregate. Fine aggregate hoppers are usually loaded by a clamshell or front-end loaders; coarse aggregate hoppers are usually loaded by conveyors.

Each storage hopper or storage hopper compartment can be discharged into a WEIGH BOX, which can in turn be discharged into a mixer or a batch truck. When a specific weight of aggregate is called for, the operator sets the weight on a beam scale. He then opens the discharge chute on the storage hopper. When the desired weight has been reached in the weigh box, the beam scale rises the operator closes the storage hopper discharge chute. He then opens the weigh box discharge chute, and the aggregate discharges into the mixer or batch truck.

When the aggregate batching plant is used with a bulk cement plant, the whole setup is called a CONCRETE BATCHING PLANT. If the plant is equipped with its own mixer, it is called a READY MIX plant. A plant of this type (which is often used on highway paving jobs) discharges ready-mixed concrete into dump trucks, or into AGITATOR trucks, if the concrete is to be transported a long distance.

Since the NMCB manpower allowance provides for an "EA" with a "Construction Inspector" NEC to monitor the quality of batching mixtures, the "EO" will not be required to know what proportions of material go into making the different concrete mixes. The "EO" will be responsible for the assembly and disassembly, upkeep and maintenance, the operation of related and supporting equipment to the plant, and the operation of the plant to produce mixes as specified by the "Construction Inspector".

CONCRETE TRANSIT MIXER

The concrete transit mixer is a production tool designed to deliver and mix concrete. You,

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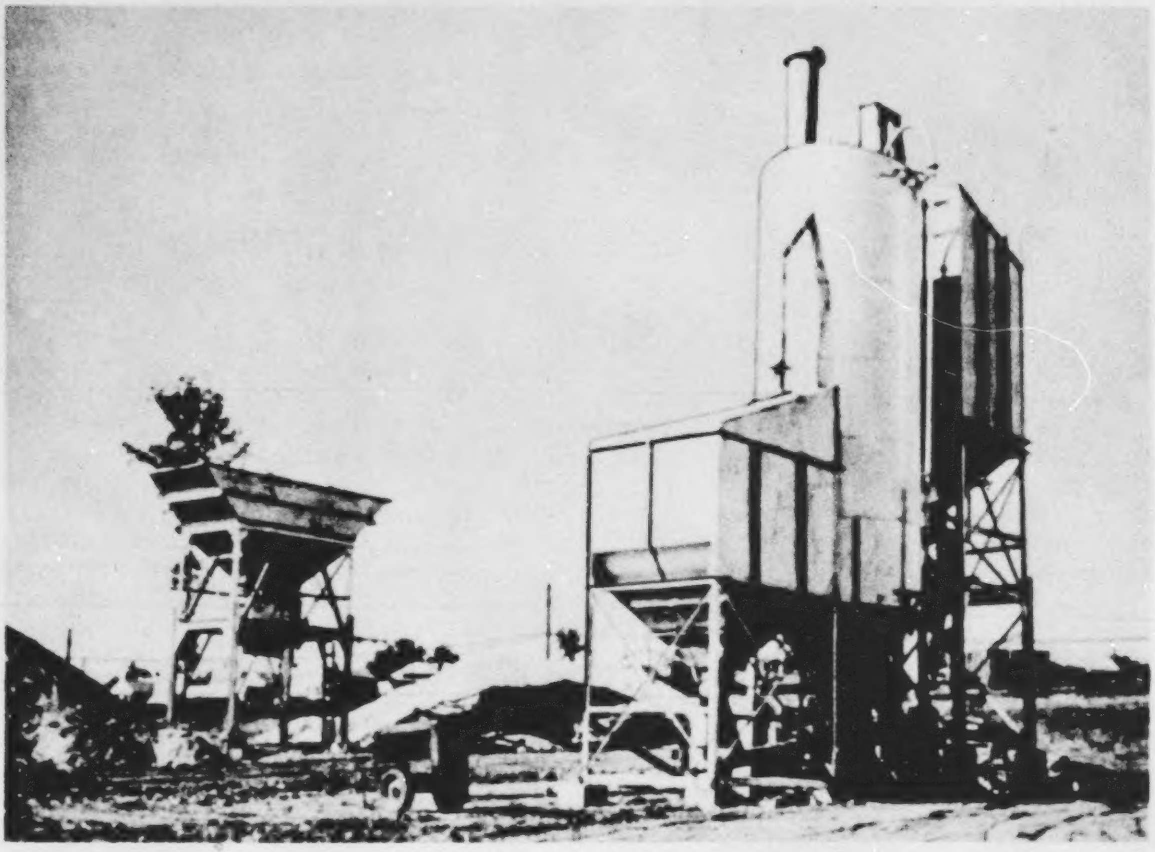

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Figure 9-1.—Aggregate and cement batching plant.

as an EO, are responsible for the safe and timely delivery of your load. You are also responsible for manufacturing concrete and safeguarding the quality of the concrete en route to and at the jobsite until the concrete has been discharged.

TRANSIT MIXER CONTROLS

The information given below is on the Challenge series 01 concrete transit mixer (fig. 9-2), and applies ONLY to that machine. This information will give you an idea of how one of the several types of transit mixers used by the SEABEES is operated.

Before operating the transit mixer, you should first become familiar with its controls (fig. 9-3). The purpose of the various controls is explained below; the numbers in parentheses correspond to those used in figure 9-3 to indicate the location and purpose of the controls.

The CLUTCH LEVER (1) is known as the "Uni-Lever" in that the actions of the clutch, throttle, and drum rotation are incorporated in the one lever. The "Uni-Lever" located at the rear of the mixer has three functions. In addition to serving as clutch and throttle, the lever also controls the direction of drum

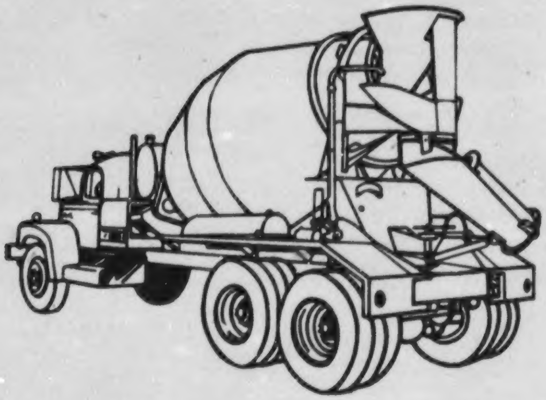

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Figure 9-2.—Concrete transit mixer.

rotation. The shifting of drum rotation may be accomplished ONLY at the rear station (2).

The HAND THROTTLE (3) is mounted on the auxiliary frame runner at the left front control station. The hand throttle is used (1) to regulate engine speed while charging the mixer, (2) to set the engine speed for transit, and (3) for any other applications which may require a constant engine speed.

The CHARGING RANGE CONTROL LEVER (4) is located on the UPPER left corner of the instrument panel at the front control station. This lever is mechanically connected to the two-speed transmission; this gives the operator an additional speed range for charging. To select the desired speed range, disengage the clutch, select the appropriate speed range, and reengage the clutch.

Before you can fulfill your responsibility as a transit truck mixer operator, some basic knowledge of the nature of concrete and of its proper mixing procedures must be known.

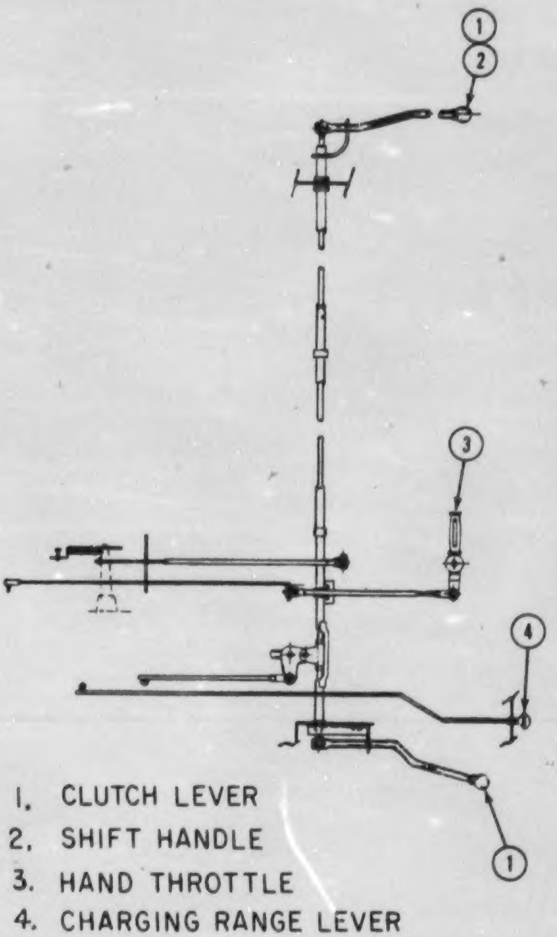

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Figure 9-3.—Transit mixer controls.

The basic ingredients of concrete are aggregates (such as gravel and crushed stone), sand, cement, and water. Small quantities of admixtures may also be added to achieve certain characteristics such as air entrainment or better workability. The aggregates normally comprise approximately 65 to 80 percent of the total volume of ingredients, while the cement and water together comprise about 20 to 35 percent.

Various kinds of concrete are produced to meet specific needs in construction work. Concrete of the desired quality is obtained by varying the sizes, types, and quantities of aggregates, as well as the type and amount of cement, the amount of water, and the types and amounts of admixtures. The kinds and quantities of each material are spelled out in a "mix design" for specific jobs and are standardized for many jobs that are similar in nature.

TYPES OF MIXER OPERATION

The transit truck mixer is used with any type of ready-mix concrete mixing and hauling procedure, including central mixing, shrink mixing, transit mixing and jobsite mixing. In hauling central mixed concrete the truck mixer serves as an agitator keeping the concrete well mixed en route to the job by turning the drum at agitating speed. In shrink mix operations the materials are combined and the mixing process is begun at the plant. Then the concrete is loaded into the mixer, and the mixing is completed in the truck mixer. In transit mixing the materials are loaded into the truck mixer at the plant, and all of the mixing is accomplished by the truck mixer en route to the job. Some project plans specify that the concrete must be mixed at the jobsite. On this type of operation, all the materials except the water are loaded into the truck mixer drum at the plant. The mixer, equipped with one of the optional large water tanks and water measuring devices, adds the mixing water at the jobsite and performs the entire mixing operation there.

IDEAL MIXING CONDITIONS

Ideal conditions for mixing concrete include simultaneous loading of cement, sand, water and aggregate (to obtain initial intermingling of materials), followed by 70 to 100 turns of the mixer drum at normal mixing speeds of approximately 7 to 11 rpm. Of these three critical steps: proper charging, adequate drum speed, and the correct number of drum revolutions during the mixing cycle, the charging operation (described later in this chapter) is the most important.

Any variations from simultaneous loading will make mixing more difficult and will require additional drum revolutions at mixing speed.

AVOID OVERMIXING

Overmixing damages the quality of the concrete, tends to grind the aggregates into smaller pieces, increases the temperature of the mixture, lowers the slump, decreases air entrainment, and decreases the strength of the concrete. Overmixing also puts NEEDLESS WEAR on the drum and blades.

In selecting the best mixing speed for each trip, the operator of a transit mixer should estimate the travel time (in minutes) to the job and divide this into the minimum desired number of revolutions at mixing speed—70. The result will be the best drum speed. For instance, if the haul is 10 minutes, 70 divided by 10 equals 7. With this drum speed, the load will arrive on the job with exactly 70 turns at mixing speed—no overmixing and no unnecessary equipment wear. If the load cannot be discharged immediately, the driver should turn it at 2 rpm (minimum agitating speed) until he can discharge it. Since he arrived on the job with no more than the minimum number of mixing turns completed, he is able to wait longer (if necessary) without accumulating more than the maximum permissible number of total turns (250).

To simplify the selection of proper mixing speeds and to allow a margin for error that will cover variations in driving conditions, the operator may choose to use mixing speeds between 5 and 10 rpm, rather than 4 to 12 rpm. Working within the 5 to 10 rpm range, dividing 70 by estimated travel time will produce the desired drum speed for any trip from 7 to 14 minutes in length. For trips shorter than 7 minutes, the driver will continue to turn his drum at 10 rpm for the full 7 minutes, even though a portion of that time is at the jobsite. For trips longer than 14 minutes in length, the driver will maintain a drum speed of 5 rpm for 14 minutes (producing a total of 70 turns at mixing speed), then change to 2 rpm (agitating speed) for the balance of the trip, and for waiting time on the job, if any.

BATCHING AND CHARGING PROCEDURES

In order to produce quality concrete, you should strive to obtain uniform ribbon loading of all materials throughout the entire charging operation. Ribbon loading is best because it allows intermingling of the materials as they enter the drum, providing a head start on the mixing operations.

For transit mixing and jobsite mixing, the mixer should be charged with the truck engine running at near full throttle and the mixer control lever in the charge position. This will produce a drum speed of about 16 rpm. For central mix and shrink mix operations a little less throttle, which will produce a charge speed of 12 to 14 rpm, is generally adequate. As soon as the load is charged, the hand throttle or remote throttle should be closed and the drum speed reduced to the desired mixing speed.

DISCHARGING

The unloading operation can be controlled from the control station at the rear or from the cab, whichever seems to best suit the job conditions. In either case, the throttle should be set partially open and the discharge speed controlled with the mixer control lever. Returning the control lever to its neutral position will automatically stop the drum. If the interruption is of any significant length, the control lever should be moved to agitate speed. The load can also be discharged with the truck in motion if required, such as in curb and gutter placement. With the mixer engine throttle positioned for slow speed, the "Uni-Lever" can be moved to whatever position will produce the needed discharge rate to fill the forms.

When discharging concrete from a mixer equipped with a sealing door, the door should be opened wide to prevent segregation or straining of materials. When discharging is intermittent as in wheelbarrows, buggies, buckets, etc., the rate should be controlled by manipulation of the mixer control lever–not the engine throttle.

MIXER CLEANING

At the jobsite: Immediately after discharging all concrete to the required project, you should wash off the excess concrete in the mixer drum and blades, the discharge opening, and the discharge chutes before it has a chance to harden. Spraying 15 to 25 gallons of water into the drum while it is revolving will clean the inside of the drum as well as remove all grout which may have collected in the water nozzle during discharge. This may be carried back to the plant and subtracted from the next load. A washdown hose is provided to clean areas accessible from the outside. A clean mixer produces a more satisfactory mixing and discharging of concrete.

CAUTION: Wash the mixer with water only for the first 30 days of operation. Any stains occurring within the first 30 days can be washed off with a mild detergent. Thoroughly rinse with clear water. Avoid washing in the sun. The use of acids or abrasives may cause severe loss of gloss.

At the plant: A minimum of 150 to 250 gallons of water, depending on the size of the mixer, should be used to thoroughly clean the drum immediately at the end of each day's run. With the flush water in the drum, rotate the drum in the mixing direction for a few minutes, then discharge the flush water at maximum drum rpm. Complete cleaning the outside of the mixer, particularly around the discharge end.

After the initial 30 days, use a mixture of half paraffin oil and half diesel on the outside of the truck and concrete mixer which can be sprayed in a few minutes; this prevents or retards the concrete from adhering to the structural members. After the entire unit has been thoroughly sprayed, it can be washed down with an ordinary garden hose at the prescribed line pressure.

If the above procedure is followed daily, it will result in increased efficiency, as well as reduce maintenance costs of the equipment.

HYDRAULIC CHUTE HOIST

The manual hydraulic chute hoist is simple to operate and requires very little maintenance. This hoist consists of an oil reservoir and a hydraulic pump with a flow control valve and a hydraulic cylinder secured to the chute. By hand pumping and manipulation of the flow control valve, the operator may raise, hold, or lower the chute to any desired position.

Hints for trouble free operation:

1. Check oil level in reservoir.
2. Keep breather on top of reservoir clean. If this breather becomes clogged, a vacuum will result.
3. Use clean oil when adding oil.

The friction lock chute brake is designed to control the swing of the chute through a 180° range. The operator may lock it at any position simply by tightening down on the handle, or it may be desirable to apply just enough drag so that a slight tug will move the chute. This arrangement may save damage to the chute in case it is forced against a solid object.

SECURING

When securing a concrete transit mixer, position the concrete discharge chute so that it is parallel to the mixer drum. Wash down the unit as described in previous paragraphs, place mixer controls in neutral, and secure mixer engine. Drive the transit truck to the designated securing area and position in a safe manner. Secure the truck as described.

OPERATOR'S CARE AND MAINTENANCE

Each operator of the concrete transit mixer is required to perform certain daily maintenance services. This maintenance includes the required inspection service, lubrication, and adjustments required to maintain the concrete transit mixer in a safe and operable condition, prevent malfunctions, and avoid or delay major repairs.

In order to maintain efficient operation of the mixer, it is important that you clean the mixer thoroughly once a day, in addition to washing it down after discharging each load. Lubricate the mixer and the mixer engine daily, in accordance with the manufacturer's instructions. Service the engine air filter regularly, check the truck frame and mixer mounting bolts, and maintain correct drum chain adjustment.

Oils which are used in the hydraulic system perform the dual function of lubrication and transmission of power. Select and use only the type recommended by the manufacturer.

Special worm gear or compound steam cylinder oil is used in the worm gear drive. Do not use automotive or hypoid type "all purpose" oil. Do not add any compound. Check oil level daily, change oil after 2 weeks of operation and every 3 months thereafter. The oil capacity is given on the instruction plate attached to the mixer housing.

The frequency of oil change and oil filter element replacement for the mixer engine depends upon the operating conditions encountered. Under normal operating conditions, the oil and filter element should be changed after every 100 hours of operation.

Since engines used in mixers may vary, it is advisable that you comply with the recommended oil viscosity, general care, and maintenance procedures outlined in the manufacturer's operating manual.

The lubricant used on the mixer roller chain must be thin enough to enter a chain joint and must be applied frequently enough that a film of lubrication is constantly maintained inside the joints. A coating of hard grease will collect and hold abrasive particles, resulting in undue wear on both chains and sprockets. To prevent corrosion, reduce wear rate of chains, and lengthen sprocket life, use of SAE 30 engine oil is recommended by the manufacturer for mixer chain lubrication. Apply oil to the chain joints daily with an oil can or brush.

TRANSIT MIXER SAFETY

The increased use of transit mix trucks on construction projects imposes traffic problems which must be considered. Caution must be used during backing of the transit truck. Backing should be controlled by a signalman, positioned so that the operator can clearly observe the directions given.

Use extreme caution when traveling over uneven terrain on a construction site. The stability of the mixer is greatly reduced with the extra weight of the concrete in the mixer unit. In such cases, a slow speed is recommended.

Some additional safety precautions that must be observed are as follows:

1. Reduce speed before making a turn or applying the truck brakes.
2. Secure discharge chute properly, using the friction brake lock provided.
3. Check to make certain that other personnel are in the clear before starting the mixer charging or discharging.
4. Before making any adjustments, make certain that the mixer engine is not running; this is particulary important when the clutch or drum chain is to be adjusted.
5. Secure mixer engine before refueling.

SLIP-FORM PAVER

The slip-form paver (fig. 9-4) is a concrete laying machine that eliminates the need for conventional paving forms or form-riding equipment. In a single pass, this machine spreads, forms, compacts, finishes, and belts the concrete while controlling the width, thickness, alinement, and riding surface of the pavement well within the specified project requirements.

OPERATING CHARACTERISTICS

The basic components of the slip-form paver are the spreading screws and strike-off assembly, vibrating beam, tamper bars, extrusion plate, finishing belts, left and right crawler assemblies, power unit (10-kilowatt electric generator driven by a gasoline engine), and operator's deck with control console. The paver's traction power is supplied by two 2-horsepower electric motors which drive the tracks through a 100 to 1 reduction gear.

The concrete used in slip-form paving operations must have a uniform consistency and be placed upon a well-compacted, accurately graded base to ensure a smooth, uniform

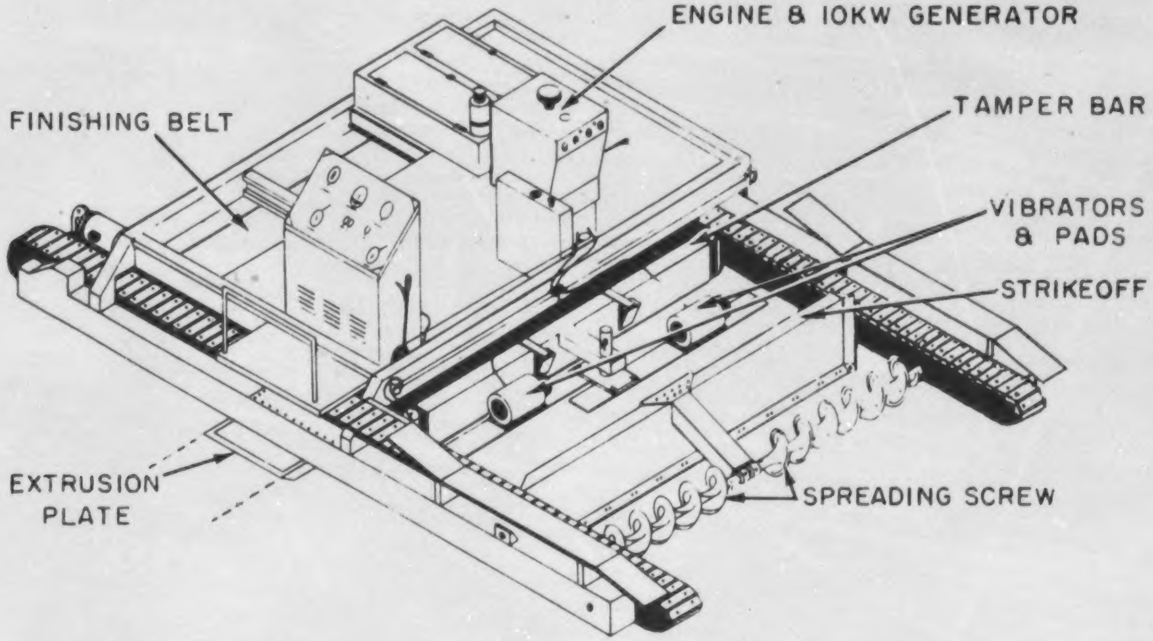

Figure 9-4.—Slip-Form paver.

concrete slab with excellent riding characteristics. The concrete should have a slump of 1 inch but not more than 3 inches.

During actual operation, concrete is evenly spread in front of the strike-off screw and between the slip-forms slightly higher than the desired slab thickness. It is struck off by the strike-off screw and vibrated with a beam vibrator, and then tampered by the tamping bars. As the paver continues forward, the concrete is pressed down and squeezed out behind the extrusion plate under the weight of the machine. This pressure consolidates the concrete and contributes to the high stability and lack of slump when the trailing forms pass on. Following the extrusion plate, a 24-inch wide finishing belt dresses the surface of the pavement. Finally, as the attached trailing forms are pulled forward, a burlap drag adds texture to the finished surface. The paver controls are located on the operator's console.

The production rate of the slip-form paver is normally governed by the amount of concrete placed in front of it (plant output). The paver, operating at regulated width (24 feet), maximum paving thickness (10 inches), and fastest paving speed (12 fpm) will lay 532.8 cubic yards of concrete per hour.

PAVER CONTROLS AND INSTRUMENTS

There are various paver controls and instruments with which the operator should be familiar. A brief description on these controls and instruments is given below.

The HYDRAULIC STRIKE-OFF SCREW LEVERS (fig. 9-5) are two three-position (left, neutral, and reverse) ball-handled control levers, located near the operator's control panel. The levers each operate a two-way valve, which is used to move concrete from the center of the strike-off to the right, to move concrete from

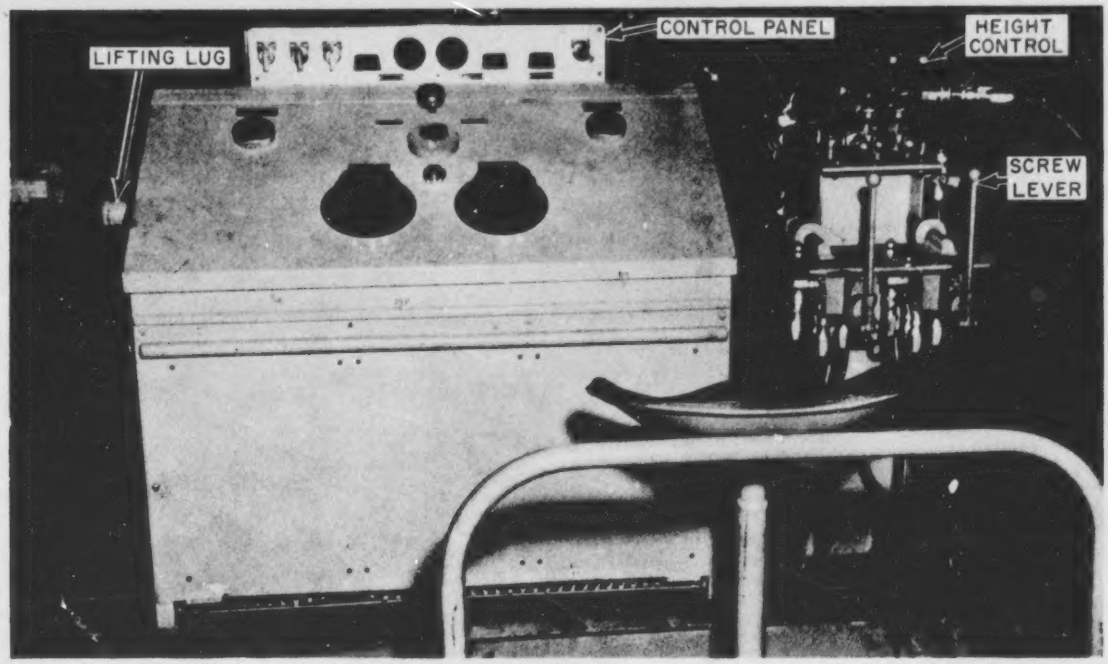

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Figure 9-5.—Operator's control area.

the center of the strike-off to the left, and to bring concrete to the center of the strike-off by reversing either or both of the preceding lever actions.

The HYDRAULIC STRIKE-OFF LEVELING LEVERS (fig. 9-5) are two three-position (up, neutral, and down) ball-handled control levers, that are located near the operator's control panel. The levers are used to raise and lower the strike-off screw assembly. NOTE: Hesitate momentarily before reversing fluid flow. Shock action can damage lines and components.

The CLUTCH CONTROL is of the lever type, mounted on the drive shaft. It provides a means of engaging and disengaging the drive belts to the generator and the drive shaft for the hydraulic pump.

Figure 9-6 shows a number of controls that are mounted on the operator's control panel. The name of each of these controls and the purpose of each, beginning at the upper left and going to the right, are as follows:

The TAMPER BAR SWITCH is a three-position type that provides an off position and a selection for automatic or manual operation of the tamper.

The BELT SWITCH is a three-position type that provides an off position and a selection for automatic or manual operation of the belt.

The VIBRATORS SWITCH is a three-position type that provides an off position and a selection for automatic or manual operation of the vibrators.

The VOLTMETER flanking the two green lights indicates the amount of voltage to each track, left and right.

The two green lights, when illuminated, indicate power on at the left or right traction motors.

The VOLTMETER (DC SUPPLY) is an electrically operated meter which can register up to 300 volts. It indicates the total amount of voltage to the console panel.

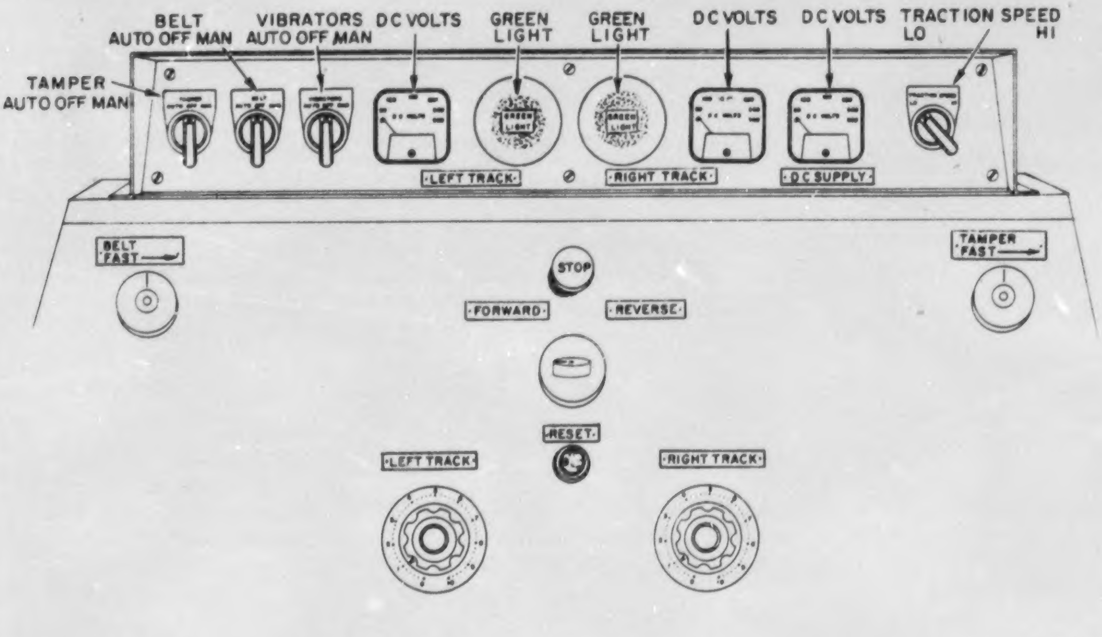
BELT
AUTO OFF MAN
VIBRATORS
AUTO OFF MAN
DC VOLTS
GREEN
LIGHT
GREEN
LIGHT
DC VOLTS
DC VOLTS
TRACTION SPEED
LO
HI
TAMPER
AUTO OFF MAN
GREEN LIGHT
GREEN LIGHT
·LEFT TRACK·
·RIGHT TRACK·
·DC SUPPLY·
BELT
FAST
TAMPER
FAST
STOP
·FORWARD·
·REVERSE·
·RESET·
·LEFT TRACK·
·RIGHT TRACK·

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Figure 9-6.–Operator's control panel.

The TRACTION SPEED SELECTOR is a two-position switch used in the "lo" position while operating and moved to "hi" (and used with caution) when moving between jobsites.

The BELT FAST RHEOSTAT regulates the revolutions per minute of the belt.

The EMERGENCY STOP SWITCH is located under the two green lights; and depressing it eliminates all power to the console panel. To begin operation after the stop switch has been engaged, push the reset switch. Next return the left and right track variac controls to "O".

NOTE: Use the emergency stop switch button only for emergencies. Pushing this switch can cause the electric drive motor fields to become saturated with high voltage and eventually ruin the motors.

The TAMPER FAST RHEOSTAT regulates the revolutions per minute of the tamping bar.

The DIRECTIONAL SELECTOR provides a selection for forward or backward movement of the machine.

The VARIACS (left and right track speed selectors) provide a means for selection of traction speeds. They also provide for independent driving of the left and right traction speeds.

NOTE: 250 volts is required on the d-c supply voltmeter and a minimum of 208 volts on the a-c generator gage before moving the machine.

The EMERGENCY RESET SWITCH between the variacs is to restart the machine after the emergency stop switch has been used.

PILE HAMMERS

The information given in this section is taken from the operator's manual for the McKiernan-Terry (often referred to simply as MKT) pneumatic and diesel pile hammers. It applies ONLY to these hammers, which are used by the Naval Construction Force.

The three principal types of pile hammers are the DROP, PNEUMATIC, and DIESEL. A drop hammer is a block of metal which is run up to a specified height and then dropped on a cap placed on the butt or head of the pile. Drop hammers range from 1200 to 3000 pounds.

The drop hammer has been to a large extent superseded by the pneumatic hammer shown in figure 9-7. This hammer consists of a cylinder which contains an air-driven RAM. The ram consists of a PISTON equipped with a

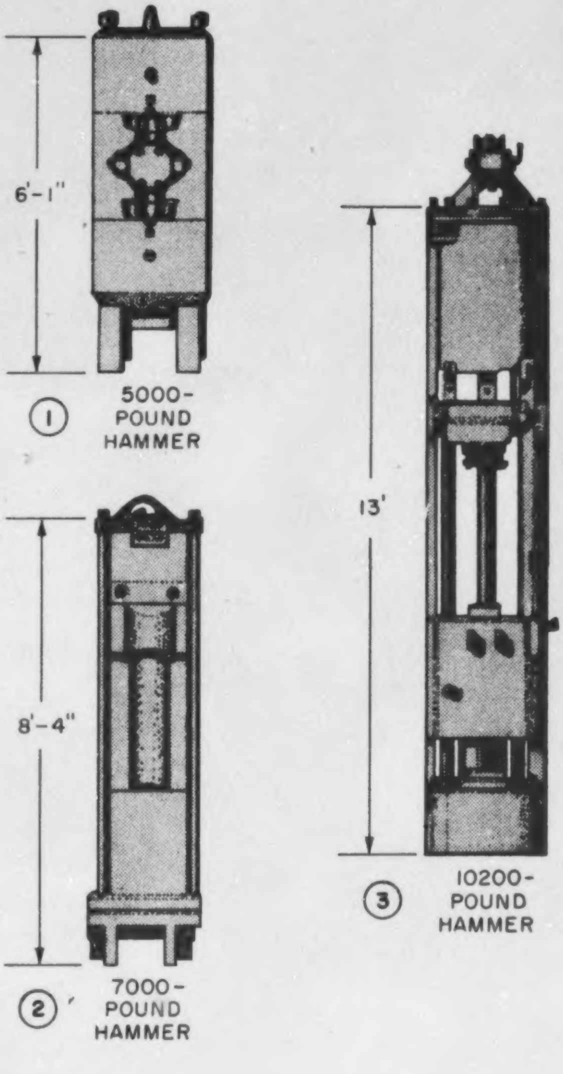

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Figure 9-7.—Steam or pneumatic pile hammer.

STRIKING HEAD. The hammer is rested on the butt or head of the pile for driving.

A SINGLE-ACTION pneumatic hammer is one in which the power drive serves only to lift the ram; the downward blow of the ram is the result of the force of gravity only. In a DOUBLE-ACTION hammer the ram is both lifted and driven downward by the power drive. A double-action hammer weighs from 5000 to 14,000 lb, a single-action hammer about 10,000 lb.

The blows of the double-action hammer are lighter but more rapid than those of the single-action hammer. The double-action hammer is generally used to drive lightweight or averageweight piles into soils of average density; its rapid blows tend to keep the pile in motion and thereby reduce the resistance caused by inertia and friction. For heavy piles in hard or dense soil, however, the resistance caused by inertia and friction, together with the rapid, high-velocity blows of the double-action hammer, tend to result in damage to the butt or head of the pile.

The single-action hammer is generally used to drive heavy piles into hard or dense soil; its heavy ram, striking at lower velocity, allows more energy to be transferred into motion of the pile, thereby reducing impact and the possibility of damage to the butt or head of the pile.

The diesel pile hammer is about twice as fast as a conventional pneumatic hammer of comparable size and weight. A conventional pneumatic hammer requires a 600-cu ft/min compressor to operate, while the diesel is a self-contained unit that is constructed in sizes capable of delivering up to 43,000 ft lb of energy per blow.

The McKiernan-Terry pile hammer illustrated in figure 9-8 is made up of a cylinder, ram-piston, fuel pump, built-in fuel tank (which holds supplies for three days without refueling), lubricant oil tank (which holds lubricant supplies for three days), and an inertia oil pump that mechanically lubricates during operation.

Operation of the McKiernan-Terry diesel pile hammer is illustrated in figure 9-9. The hammer is worked by a single crane load-line (A). It is started by lifting the ram-piston (B) with the load-line until the trip mechanism (C) automatically releases the ram-piston. The ram-piston falls, actuating the cam of the fuel pump (D), which delivers a measured amount of diesel fuel that falls into a cup formed in the top of the anvil (E). Continuing its downward fall, the ram-piston blocks the exhaust ports (F) and begins compression with air trapped between the ram-piston and the anvil. The compression creates a preloading force upon the anvil, drive cap, and pile. The gravity propelled ram-piston strikes the anvil, delivering its impact energy to the pile.

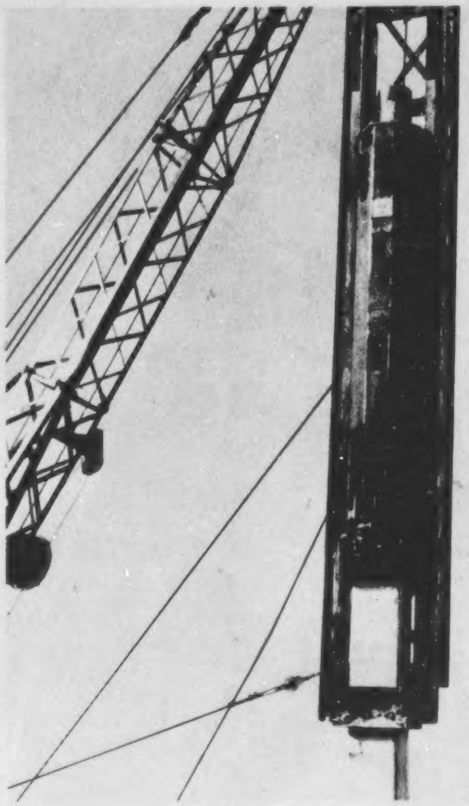

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Figure 9-8.–McKiernan-Terry diesel pile hammer.

The rounded end of the ram-piston mates perfectly with the cup in the anvil, displacing

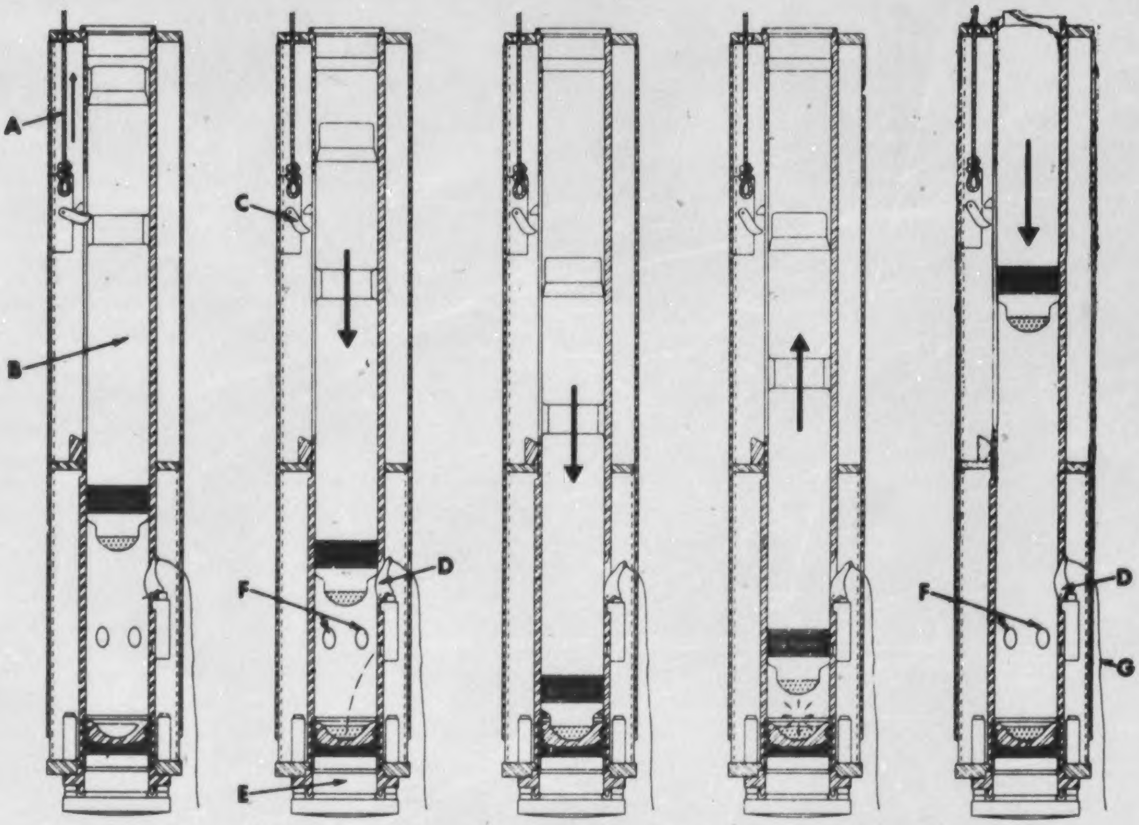

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Figure 9-9.—Operating principles of the McKiernan-Terry diesel pile hammer.

the liquid fuel at the precise moment of impact to achieve perfect timing. The fuel is atomized and splattered into the annular (ring-shaped) zone between the ram and the anvil and is ignited by the heat of compression.

The resulting explosive force drives the ram-piston upward and the pile downward, adding a push to the pile to extend the time duration of the total effort to drive the pile.

On the upstroke, the ram-piston opens the exhaust ports (F) to permit scavenging the exhaust gases. The ram-piston continues freely upward until arrested by gravity. The length of the stroke varies with the resistance offered by the pile. The greater the resistance, the longer the stroke.

Having reached the top of its stroke, the ram-piston falls again, repeating the cycle. The hammer is stopped by pulling a rope (G), disengaging the fuel pump cam (D).

The diesel pile hammer which you will use may not be the same make or model as the one described in the preceding paragraphs, but you will find that the operating principles are similar.

Be sure to check the hammer oil and fuel level daily. Keep the hammer fuel pump check valve clean by unscrewing the nut and wiping off the rubber tip.

Drive cap lashing cables should be checked for breakage or excessive wear.

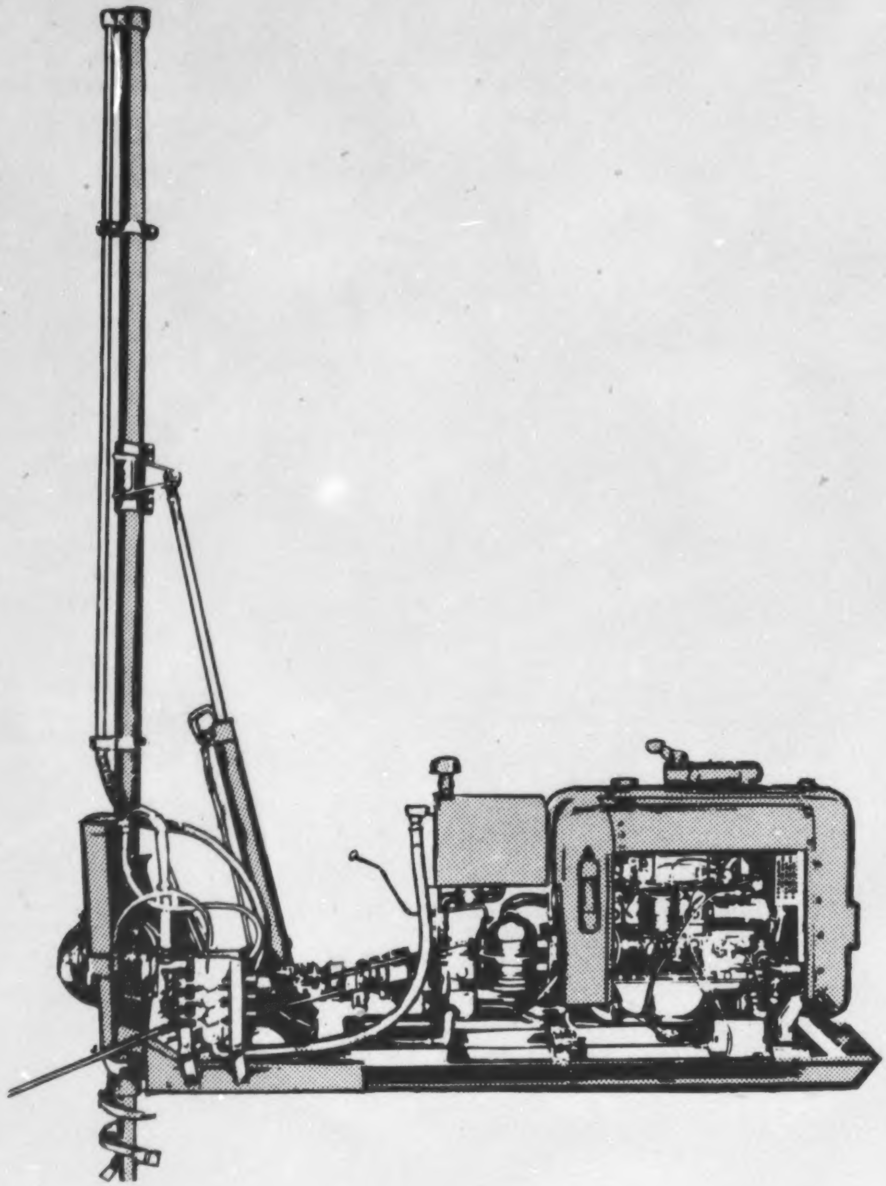

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Figure 9-10.—Power earth auger.

Check hammer bolts and nuts for tightness, especially if difficult piledriving is encountered.

Be sure to observe all safety and accident prevention procedures applicable to piledriving operations. Be sure you and your crewmembers wear hard hats, safety shoes, and safety goggles.

POWER EARTH AUGER

The power auger (fig. 9-10) is a self-contained, hydraulically operated and positioned earth-boring machine. Normally mounted on the bed of a truck, the earth auger is powered by a gasoline engine. In subsurface soil explorations, this auger can bore holes up to 20 inches in diameter and 9 feet in depth. The holes can be bored vertically downward or at angles up to 45°. The power auger can also remove soils for testing.

The auger assembly consists of the auger, kelly bar, final drive assembly, and right-angle drive assembly. Operation of the boring assembly is controlled by the auger clutch, which engages and disengages the kelly bar. Placement of the hydraulic valve levers enables the operator to observe the boring operation and the engine instruments at the same time.

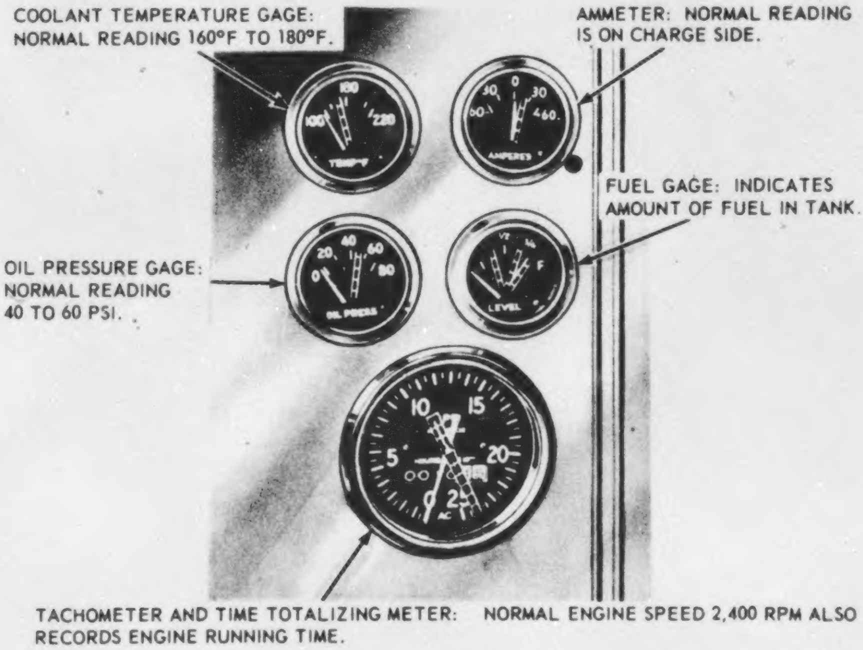
OPERATION OF POWER EARTH AUGERS

Since the operating procedure may vary among different makes and models of earth augers, be sure to consult the manufacturer's manual for the specific earth auger being used. The basic procedure for operating the Texoma Enterprises earth auger, Jaques model TJ 254, is given below. Figure 9-11 shows the instruments of this earth auger and normal instrument readings. Figure 9-12 identifies the controls and their uses.

NOTE: Before starting or operating the earth auger, be sure you and your crewmembers wear hard hats, safety shoes, and goggles.

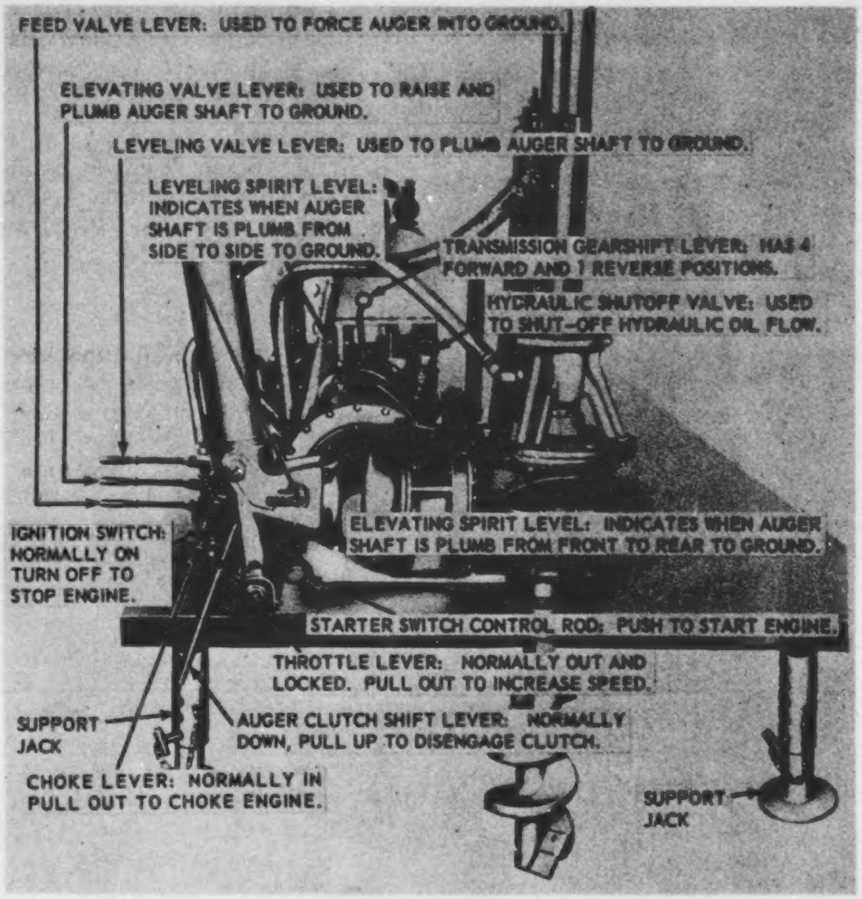
Starting the Power Earth Auger Engine

First, perform the routine prestart checks of the engine crankcase oil level, transmission oil level, fuel supply, battery water level, coolant level, and hydraulic oil level. Be sure that the proper amount of lubricant, water, and electrolyte is added, when required. Next, place all controls in the neutral position. Then open the fuel shutoff valve and the hydraulic oil


COOLANT TEMPERATURE GAGE: NORMAL READING 160°F TO 180°F.
AMMETER: NORMAL READING IS ON CHARGE SIDE.
FUEL GAGE: INDICATES AMOUNT OF FUEL IN TANK.
OIL PRESSURE GAGE: NORMAL READING 40 TO 60 PSI.
TACHOMETER AND TIME TOTALIZING METER: NORMAL ENGINE SPEED 2,400 RPM ALSO RECORDS ENGINE RUNNING TIME.
100
180
220
TEMP°F
AMPERES
0
20
40
60
80
OIL PRESS
LEVEL
F
5
10
15
20

115.485

Figure 9-11.—Instruments, power earth auger.


FEED VALVE LEVER: USED TO FORCE AUGER INTO GROUND.
ELEVATING VALVE LEVER: USED TO RAISE AND PLUMB AUGER SHAFT TO GROUND.
LEVELING VALVE LEVER: USED TO PLUMB AUGER SHAFT TO GROUND.
LEVELING SPIRIT LEVEL: INDICATES WHEN AUGER SHAFT IS PLUMB FROM SIDE TO SIDE TO GROUND.
TRANSMISSION GEARSHIFT LEVER: HAS 4 FORWARD AND 1 REVERSE POSITIONS.
HYDRAULIC SHUTOFF VALVE: USED TO SHUT-OFF HYDRAULIC OIL FLOW.
IGNITION SWITCH: NORMALLY ON TURN OFF TO STOP ENGINE.
ELEVATING SPIRIT LEVEL: INDICATES WHEN AUGER SHAFT IS PLUMB FROM FRONT TO REAR TO GROUND.
STARTER SWITCH CONTROL ROD: PUSH TO START ENGINE.
THROTTLE LEVER: NORMALLY OUT AND LOCKED. PULL OUT TO INCREASE SPEED.
SUPPORT JACK
AUGER CLUTCH SHIFT LEVER: NORMALLY DOWN, PULL UP TO DISENGAGE CLUTCH.
CHOKE LEVER: NORMALLY IN PULL OUT TO CHOKE ENGINE.
SUPPORT JACK

115.486

Figure 9-12.–Controls, power earth auger.

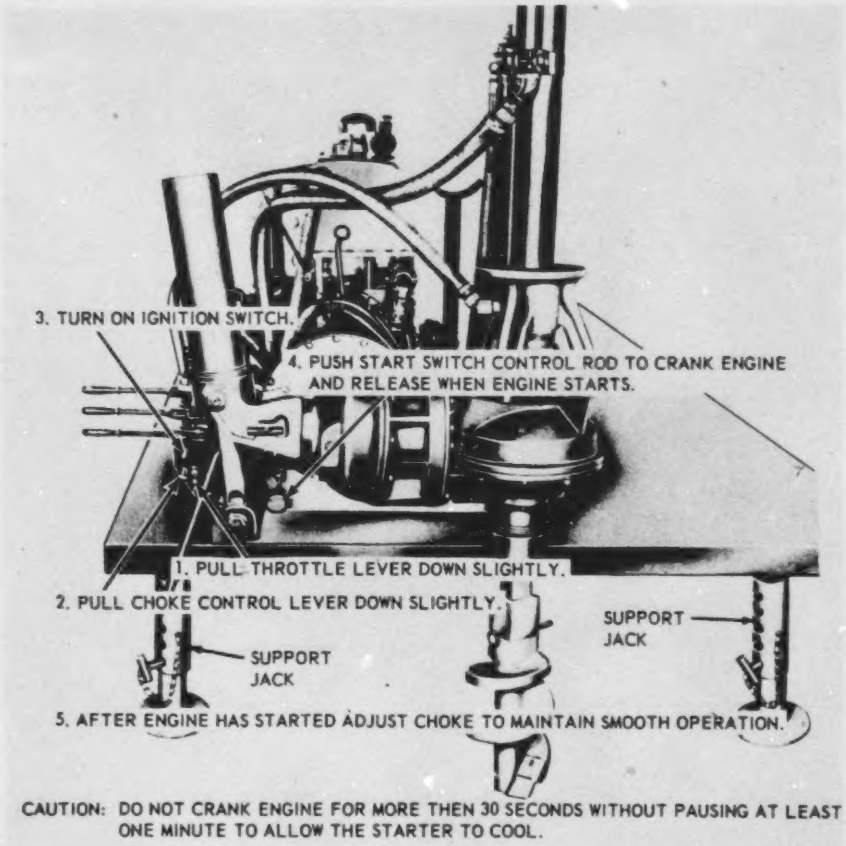
shutoff valve. By following the sequence of steps given in figure 9-13, you should be able to start the auger engine.

Steps for Auger Operation

Follow the procedures below to place the power earth auger in motion after the engine has been started:

1. Disengage the engine clutch and shift the transmission into fourth gear.
2. Engage the engine clutch and run the engine at idle speed.
3. Pull the elevating valve lever to elevate auger shaft into the vertical position and plumb as indicated by the elevating spirit level.
4. Engage the auger clutch by pressing down on the auger clutch shift lever and allow the auger shaft to rotate for 5 minutes.

NOTE: Do not run the engine faster than idle until the auger gears are thoroughly warmed up. Remember to engage levers gradually to prevent damage to the gear cases and other moving parts.



3. TURN ON IGNITION SWITCH.

4. PUSH START SWITCH CONTROL ROD TO CRANK ENGINE AND RELEASE WHEN ENGINE STARTS.

1. PULL THROTTLE LEVER DOWN SLIGHTLY.

2. PULL CHOKE CONTROL LEVER DOWN SLIGHTLY.

5. AFTER ENGINE HAS STARTED ADJUST CHOKE TO MAINTAIN SMOOTH OPERATION.

CAUTION: DO NOT CRANK ENGINE FOR MORE THEN 30 SECONDS WITHOUT PAUSING AT LEAST ONE MINUTE TO ALLOW THE STARTER TO COOL.

115.487

Figure 9-13.—Starting the earth auger engine.

5. Disengage the engine clutch after the auger has been warmed up.

TECHNIQUES OF AUGER OPERATION

Auger operational techniques applied under ordinary circumstances are described below. Figure 9-14 shows the auger controls and how the auger is positioned using these controls.

Raising and Lowering Auger

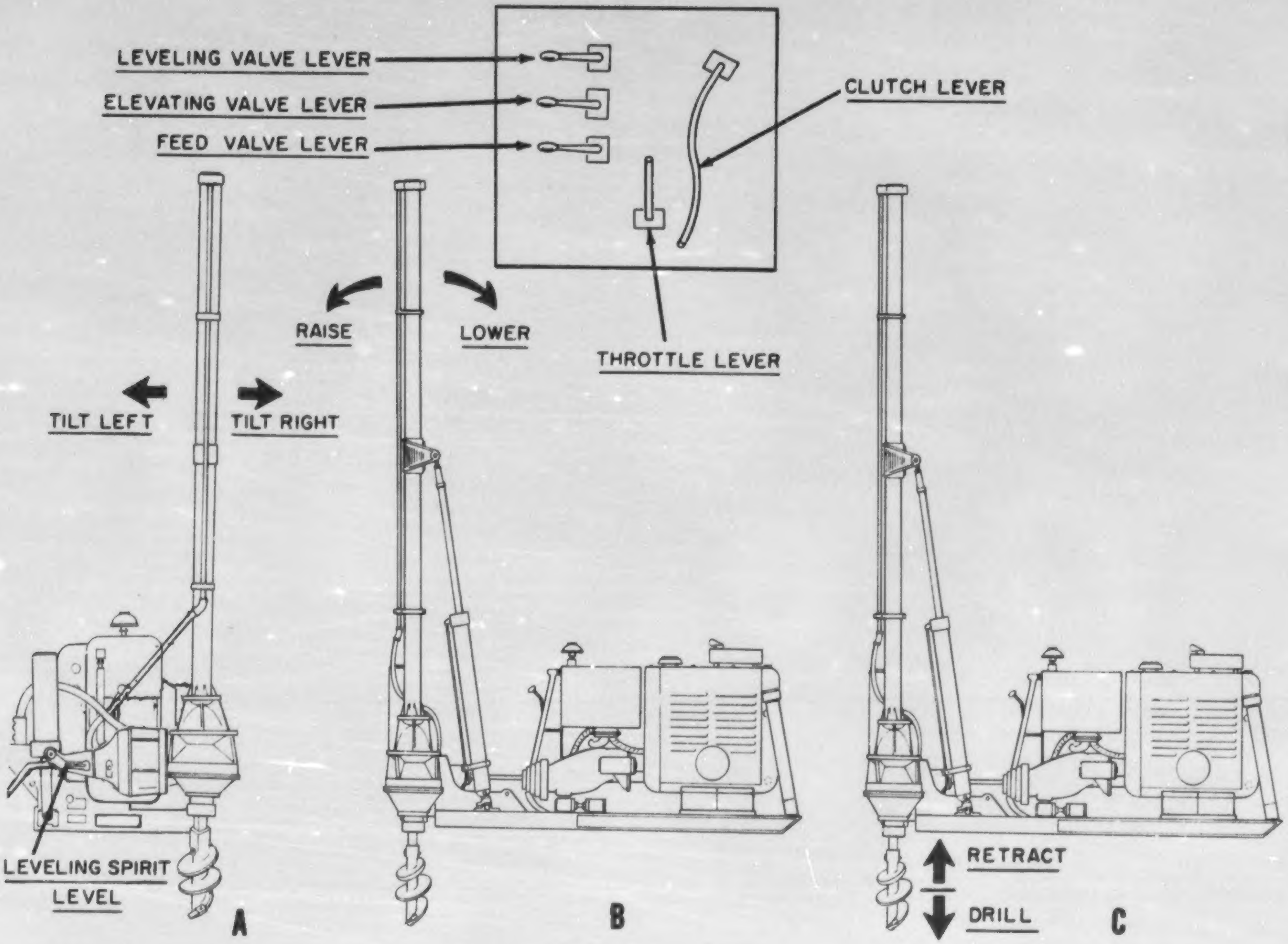
By using the ELEVATING VALVE LEVER, the auger shaft can be raised or lowered for transporting as shown in view B of figure 9-14.

Leveling Auger

By using the LEVELING VALVE LEVER, the auger shaft can be tilted to the right or left as shown in view A of figure 9-14. The LEVELING SPIRIT LEVEL should be used to plumb the auger shaft. Use support jacks when operating the auger in hardpan or rocky soil to keep the auger from bouncing.

Drilling and Retracting Auger

After the auger shaft has been placed and alined in the desired drilling position you are ready to begin drilling operations. Remember


LEVELING VALVE LEVER
ELEVATING VALVE LEVER
FEED VALVE LEVER
CLUTCH LEVER
THROTTLE LEVER
RAISE
LOWER
TILT LEFT
TILT RIGHT
LEVELING SPIRIT LEVEL
RETRACT
DRILL
A
B
C

115.489

Figure 9-14.—Using auger controls for positioning of auger.

though, do not feet the auger too quickly. Drilling operations are begun by engaging the auger CLUTCH LEVER, pulling back on the THROTTLE LEVER to increase engine speed, and then pushing forward on the FEED VALVE LEVER to lower the auger into the ground as shown in view C, figure 9-14.

CAUTION: Do not overspeed the auger. Run the engine at slow speed until the texture of the material can be determined. Don't let anyone stand close to the rotating auger or try to remove an object from the rotating auger.

When the auger is deep enough in the ground to be loaded with dirt, disengage the auger CLUTCH LEVER and pull back on the FEED VALVE LEVER to raise the auger from the hole. After the auger has cleared the hole, engage the auger CLUTCH LEVER (fig. 9-14) to rotate the auger and to clear the unit of dirt. Remember, as you raise the auger, push the hand THROTTLE forward to lower engine speed. Repeat the directions given above until the hole being drilled is at the desired depth. Don't leave the auger unattended when drilling.

Stopping the Earth Auger Engine

To stop the auger engine, observe the steps as given in figure 9-15 after disengaging the engine clutch and shifting the transmission into neutral.

SECURING

Upon completion of auger operations, cover holes in which poles or other construction material have not been place. The covering must enable crewmembers or equipment to pass safely.

When securing the truck-mounted power earth auger, position the auger for traveling and secure the auger engine. Be sure to close the fuel shutoff valve and the hydraulic oil shutoff valve. Then drive the truck to the designated securing area, and position the earth auger in a safe manner. After the truck has stopped, disengage the engine clutch, position the main transmission shift lever to neutral, engage the truck parking brake, and turn the key switch counterclockwise to the OFF position. Secure all doors and windows before leaving the truck.

AUGER CARE AND MAINTENANCE

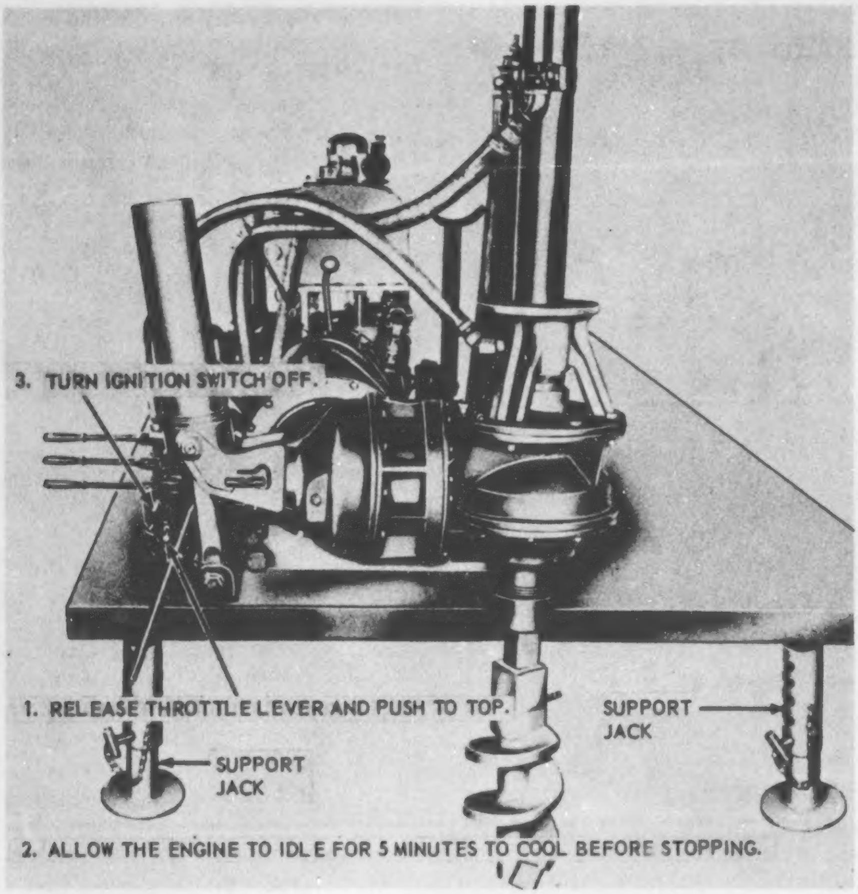
The manufacturer's maintenance manuals contain complete instructions on the care and maintenance, including lubrication requirements, for the auger. Whatever the type of auger you are operating, insure the following requirements are met:

1. Check the auger daily when in use for loose nuts and bolts and for worn parts.
2. Check the fuel, lube oil, battery, coolant levels, and hydraulic oil during prestart.
3. Fill the fuel tank at the end of each workday.
4. Wash or steam clean dirt and mud from auger at the end of each workday.

Proper lubrication of an auger is of prime importance in prolonging its life. Fuels, oils, and greases should be of a good quality and kept free of dirt, water, and other foreign matter. All level plugs or pressure grease fittings must be cleaned prior to opening for level check or prior to pressure gun installation. Be sure to secure the auger before lubricating it.

STEAM CLEANERS

Portable steam cleaners, like the oil-fired model of figure 9-16 are used to help wash mud and grease from construction and automotive equipment. Before operating the steam cleaner, you must connect it to fresh water and electricity, and fill with fuel oil. The water can be taken from a standard tap or other source, such as a well, stream, or large tank that supplies


3. TURN IGNITION SWITCH OFF.
1. RELEASE THROTTLE LEVER AND PUSH TO TOP.
SUPPORT JACK
SUPPORT JACK
2. ALLOW THE ENGINE TO IDLE FOR 5 MINUTES TO COOL BEFORE STOPPING.

115.488

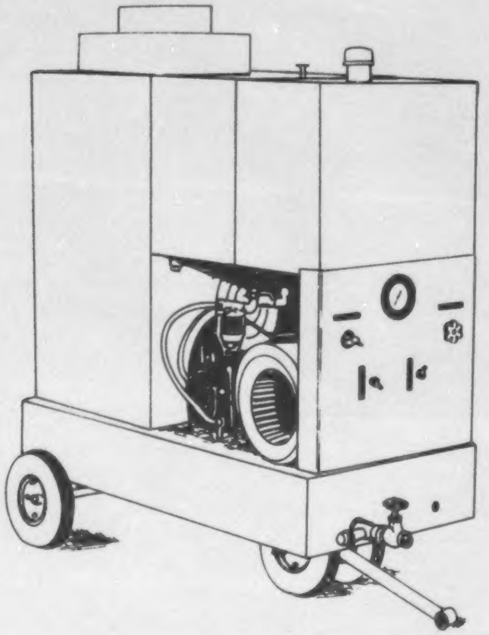
Figure 9-15.—Stopping the earth auger engine.

water at the rate of 2 gallons per minute. Some models have the means for adding liquid detergents and water softeners during operation. The main motor of the steam cleaner is powered by electricity. Depending on the model, the power source is 110-volt or 50-hertz, 220-volt alternating current. If a drop cord is needed to connect the cleaner to the power source, use one made of heavy duty wiring (No. 10 or larger). The fuel should be either the best grade of kerosene available or No. 1 or No. 2 fuel oil. Although the cleaner will operate on heavier fuels, they are usually more troublesome.

OPERATING PROCEDURES

After filling the fuel tank and connecting the steam cleaner to its water and power sources, proceed as follows:

1. Open the valve to the water source. Always keep this valve open while the cleaner is running.
2. Open the stem gun valve.
3. Turn on the pump switch to start the main motor and water pump. This forces water through the steam gun. Wait until a steady stream of water flows from the gun.



143.297

Figure 9-16.—Steam cleaner.

4. Open the fuel valve and turn on the burner switch. The fuel should ignite within two minutes and the steam gage should indicate pressure between 60 and 100 psi, which is ideal for effective cleaning.

If a liquid detergent or water softener or both can be added to the water in your steam cleaner, follow the manufacturer's instructions for doing so.

When ready to stop the steam cleaner after use, work backwards from step 4 above. Close the valves that you opened and turn off the switches. Before turning off the pump switch, however, allow the cleaner to run until cold water only flows from the steam gun.

SAFETY CONTROLS

The steam cleaner is equipped with three limiting controls—one for high temperature and two for excessive steam pressure. Each control is preset at the factory. The upper limit of the temperature control is 350°F. One pressure control is a relief valve. Although factory preset at 150 psi, it can be adjusted for lower settings.

MAINTENANCE

If hard water is used constantly in the steam cleaner, deposits of lime will tend to build up in the coil. You can remove the deposits by pumping a deliming solution (called LIME OUT) through the coil for about 15 minutes. Or, instead of pumping LIME OUT, you can mix diluted muriatic acid in your water. After deliming, flush the cleaner with fresh water. Then start the cleaner and allow it to steam for at least 10 minutes.

MATERIALS-HANDLING EQUIPMENT

The term "materials-handling equipment" refers to any stationary or mobile equipment, powered, mechanical, or hand-operated, that is used in the handling, storing or moving of supplies. Various types of materials-handling equipment are available but here we are primarily interested in the forklift.

In general, as an EO1 or EOC, you will have very little to do as far as actually operating the materials-handling equipment is concerned. Your principal duties will include determining the type and size of materials-handling equipment required for a specific job, determining the payload and rate of operation, insuring that your crews use proper techniques in performing materials-handling operations, and seeing that the job proceeds efficiently.

Generally, it will be possible from the data given in manufacturer's manuals to calculate the actual performance of a piece of materials-handling equipment. This can be verified by actual timing in operation. Manual handling of the same task can be timed and an estimate made of the savings in man-hours possible with the use of a particular piece of equipment. An example of this type of calculation is the estimate below of the tons per man-hour (T/MH) possible by using a forklift truck with pallets to unload palletized, cartoned material from a landing craft and place it in storage. Figures are based on a movement of 200 feet with loads placed on the third tier of pallets.

Example:

OPERATION	MINUTES
Pick up and transport loaded pallet to storage	0.17
Continue loaded transport 200 feet 5mph	0.45
Transport vertically (elevate 108 in.)	0.30
Position	0.08
Back away and lower	0.30
Transport empty 200 feet 5 mph	0.45
Continue transport empty into landing craft	0.08
Total	1.83
25% allowance factor	0.46
STANDARD TIME FOR ROUND TRIP	2.29

This shows 26 round trips per hour with a 2,000 pound pallet load-each trip, or a total of 26 tons for 1 man-hour or T/MH of 26.

RATINGS

The fork truck pivots on the center of the drive axle; therefore, the weight of the load ahead of the front wheels must be counterbalanced by the weight of the truck. In accordance with the principles of leverage, the ability of the fork truck to lift a load depends upon the length of the load (distance of its center of gravity from the center of the front axle of the truck) and the weight of the load.

The capacity of the fork truck is stated in inch-pounds, which is the rated pounds capacity of the truck multiplied by the distance from the center of the front axle to the center of the rated load selected by the manufacturer. In general, trucks are rated by pounds and the distance from the heel of the forks to the center of gravity of the rated load (for instance, 4,000 lbs at 24-in. load center).

To determine inch-pounds capacity of a fork truck, add to load center the distance from the center of the front axle to the heel of the forks, which can be obtained from the manufacturer's specifications or by measurement, and multiply the sum by the rated load weight. For example: Assume a rating of 4,000 pounds at 24 inches, with a measurement of 15 inches from the heel of the forks to the center of the front axle. Result: 4000 x (24 + 15) = 156,000 inch-pounds. To determine the maximum weight which may be placed on a pallet of given size, assuming uniform weight distribution on the pallet, add half the dimension of the pallet parallel to the forks to the distance from the center of the front axle to the heel of the forks and divide the sum into the inch-pound capacity of the truck. To complete the example, the maximum weight on a 40- by 48-pallet is 156,000 divided by (15 + 20), which equals 4,460. However, the load weight may not be in excess of the weight of the rated load stated by the manufacturer. If the dimension of the pallet used, parallel to the forks, is less than twice the rated load center, the rated pounds capacity is the capacity of the truck; therefore, the maximum load would still be 4,000 pounds. Bending of the mast channels as the load is raised, plus forward tilt action, will reduce the capacity of elevated loads by as much as 25 percent. Overloading of fork trucks is strictly prohibited. Among the effects of continued overload are damage to the lift mechanism, excessive tire wear, and strain on the truck frame.

SAFETY

A forklift should not be loaded beyond its rated capacity. Never load a forklift higher than the lifting rams. Lift, lower, and haul loads with upright, vertical, or tilted back. Tilting is preferable, because it steadies the load for safer hauling. Never butt loads with the fork or the rear end of the truck; you may damage the cargo. Stacking the lift too high is not recommended, because it will block your view and increase the chances of toppling the load. If you must haul a high tiered load, drive the forklift backward slowly, watching overhead clearance to avoid hitting pipes, sprinkler heads, and other projections which could cause a bad spill and a serious accident. Carry the load just high enough to clear the ground.

Forklift trucks are equipped with an overhead safety guard fabricated from steel. Exceptions are permitted only when the overhead safety guard will either increase the overall height of the fork truck or prevent the operator from having freedom of movement. Overhead guards will be capable of withstanding, without evidence of damage, a minimum drop of 5 feet of a wood box or container of 1 cubic foot in volume, weighing 100 pounds. Open spaces between steel bars or tubes will not exceed 6 inches.

The load capacity and gross weight of a fork truck are stenciled on the machine in plain view of the operator. This capacity must never be exceeded. Counterweighing of a machine to increase lifting capacity is prohibited. Capacity should be rated at 24 inches from the heel of forks.

Personnel should never stand under loads being hoisted or lowered by fork trucks.

Operators must always face in the direction of travel. All loads must be carried in such a manner that the operator's vision is unobstructed in the direction of travel.

Fork trucks transporting cargo up ramps or other grades must be operated with the load upgrade; carrying cargo downgrade.

All loads being transported must be carried with channels tipped back.

Fork trucks can be used to hoist personnel only under the following conditions:

1. Supervisor must authorize all raising and lowering of personnel by fork trucks.
2. Special "personnel pallets" with guard rails on four sides must be used.
3. During actual raising and lowering operations, all personnel must face away from mast and keep hands clear of hoisting mechanism.
4. Personnel must never be transported in an elevated position.
5. Only skilled personnel will be asked to perform tasks requiring elevation by fork trucks.

Slings or lifting pads must never be attached to the overhead guards for the purpose of lifting the vehicle.

When not in operation, the forks must be lowered and rested flat on the floor.

Stacks must never be bumped or pushed by fork trucks in an attempt to straighten them.

In all operations involving more than one fork truck, vehicles must always remain 20 feet apart unless two vehicles are transporting the same object.

APPENDIX I

ADDITIONAL TABLES RELATED TO ASPHALT

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TABLE I-1

WEIGHTS AND VOLUMES OF ASPHALTIC MATERIALS (APPROXIMATE)

Type and Grade	Pounds per Gallon	Pounds per Barrel*	Gallons per Ton	Barrels* per Ton
RC-0, MC-0, SC-0....	7.8	328	256	6.1
RC-1, MC-1, SC-1....	7.9	332	253	6.0
RC-2, MC-2, SC-2....	8.0	336	250	6.0
RC-3, MC-3, SC-3....	8.1	340	247	5.9
RC-4, MC-4, SC-4....	8.2	344	244	5.8
RC-5, MC-5, SC-5....	8.3	349	241	5.7
40-50 Pen. A.C....	8.6	361	233	5.5
60-70 Pen. A.C....	8.5	357	235	5.6
85-100 Pen. A.C....	8.5	357	235	5.6
120-150 Pen. A.C....	8.5	357	235	5.6
200-300 Pen. A.C....	8.4	353	238	5.7
Emulsified Asphalts...	8.3	349	241	5.7

* A barrel equals 42 U.S. Gallons.

Notes: 1. Since the specific gravity of asphaltic materials varies, even for the same type and grade, the weight and volume relationships shown above are approximate and should be used only for general estimating purposes. Where more precise data are required, they must be computed on the basis of laboratory tests on the specific product.

2. The approximate data shown above are for materials at 60°F.

TABLE I-2

GALLONS OF ASPHALT REQUIRED PER 100 LINEAR FEET; VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET 1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	1.1	2.2	6.7	7.8	8.9	10.0	11.1	12.2	13.3	15.6	17.8	20.0	22.2	24.4	26.7
0.15	1.7	3.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0	23.3	26.7	30.0	33.3	36.7	40.0
0.20	2.2	4.4	13.3	15.6	17.8	20.0	22.2	24.4	26.7	31.1	35.6	40.0	44.4	48.9	53.3
0.25	2.8	5.6	16.7	19.4	22.2	25.0	27.8	30.6	33.3	38.9	44.4	50.0	56.6	61.1	66.7
0.30	3.3	6.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	46.7	53.3	60.0	66.7	73.3	80.0
0.35	3.9	7.8	23.3	27.2	31.1	35.0	38.9	42.8	46.7	54.4	62.2	70.0	77.8	85.5	93.3
0.40	4.4	8.9	26.7	31.1	35.6	40.0	44.4	48.9	53.3	62.2	71.1	80.0	88.9	97.8	107.
0.45	5.0	10.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	70.0	80.0	90.0	100.	110.	120.
0.50	5.6	11.1	33.3	38.9	44.4	50.0	55.5	61.1	66.7	77.8	88.9	100.	111.	122.	133.
0.55	6.1	12.2	36.7	42.8	48.9	55.0	61.1	67.2	73.3	85.5	97.8	110.	122.	134.	147.
0.60	6.7	13.3	40.0	46.7	53.3	60.0	66.7	73.3	80.0	93.3	107.	120.	133.	147.	160.
0.65	7.2	14.4	43.3	50.6	57.8	65.0	72.2	79.4	86.7	101.	115.	130.	144.	159.	173.
0.70	7.8	15.6	46.7	54.4	62.2	70.0	77.8	85.5	93.3	109.	124.	140.	156.	171.	187.
0.75	8.3	16.7	50.0	58.3	66.7	75.0	83.3	91.7	100.	117.	133.	150.	167.	183.	200.
0.80	8.9	17.8	53.3	62.2	71.1	80.0	88.9	97.8	107.	124.	142.	160.	178.	196.	213.
0.85	9.4	18.9	56.7	66.1	75.5	85.0	94.4	104.	113.	132.	151.	170.	189.	208.	227.
0.90	10.0	20.0	60.0	70.0	80.0	90.0	100.	110.	120.	140.	160.	180.	200.	220.	240.
0.95	10.6	21.1	63.3	73.9	84.4	95.0	106.	116.	127.	148.	169.	190.	211.	232.	253.
1.00	11.1	22.2	66.7	77.8	88.9	100.	111.	122.	133.	156.	178.	200.	222.	244.	267.
1.10	12.2	24.4	73.3	85.5	97.8	110.	122.	134.	147.	171.	196.	220.	244.	269.	293.
1.20	13.3	26.7	80.0	93.3	107.	120.	133.	147.	160.	187.	213.	240.	267.	293.	320.
1.25	13.9	27.8	83.3	97.2	111.	125.	139.	153.	167.	194.	222.	250.	278.	306.	333.
1.30	14.4	28.9	86.7	101.	116.	130.	144.	159.	173.	202.	230.	260.	289.	318.	347.
1.40	15.6	31.1	93.3	109.	124.	140.	156.	171.	187.	218.	249.	280.	311.	342.	373.
1.50	16.7	33.3	100.	117.	133.	150.	167.	183.	200.	233.	267.	300.	333.	367.	400.
1.75	19.4	38.9	117.	136.	156.	175.	194.	214.	233.	272.	311.	350.	389.	427.	467.
2.00	22.2	44.4	133.	156.	178.	200.	222.	244.	267.	311.	356.	400.	444.	489.	533.
2.25	25.0	50.0	150.	175.	200.	225.	250.	275.	300.	350.	400.	450.	500.	550.	600.
2.50	27.8	55.6	167.	194.	222.	250.	278.	306.	333.	389.	444.	500.	556.	611.	667.
2.75	30.6	61.1	183.	214.	244.	275.	306.	336.	367.	428.	489.	550.	611.	672.	733.
3.00	33.3	66.7	200.	233.	267.	300.	333.	367.	400.	467.	533.	600.	667.	733.	800.

NOTE: Formula used for calculation:

$$Q = \frac{100\ W}{9} R = 11.11\ WR$$

Where:
Q = Quantity of asphalt required, in gallons per station (100 ft.)
R = Rate of application in gallons per sq. yd.
W = Width of application, in feet

Appendix I—ADDITIONAL TABLES RELATED TO ASPHALT

TABLE I-3

GALLONS OF ASPHALT REQUIRED PER MILE FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	58.7	117	352	411	469	528	587	645	704	821	939	1056	1173	1291	1408
0.15	88.0	176	528	616	704	792	880	968	1056	1232	1408	1584	1760	1936	2112
0.20	117.	235	704	821	939	1056	1173	1291	1408	1643	1877	2112	2347	2581	2816
0.25	147.	293	880	1027	1173	1320	1467	1613	1760	2053	2347	2640	2933	3227	3520
0.30	176.	352	1056	1232	1408	1584	1760	1936	2112	2464	2816	3168	3520	3872	4224
0.35	205.	411	1232	1437	1643	1848	2053	2259	2464	2875	3285	3696	4107	4517	4928
0.40	235.	469	1408	1643	1877	2112	2347	2581	2816	3285	3755	4224	4693	5163	5632
0.45	264.	528	1584	1848	2112	2376	2640	2904	3168	3696	4224	4752	5280	5808	6336
0.50	293.	587	1760	2053	2347	2640	2933	3227	3520	4107	4693	5280	5867	6453	7040
0.55	323.	645	1936	2259	2581	2904	3227	3549	3872	4517	5163	5808	6453	7099	7744
0.60	352.	704	2112	2464	2816	3168	3520	3872	4224	4928	5632	6336	7040	7744	8448
0.65	381.	763	2288	2669	3051	3432	3813	4195	4576	5339	6101	6864	7627	8389	9152
0.70	411.	821	2464	2875	3285	3696	4107	4517	4928	5749	6571	7392	8213	9035	9856
0.75	440.	880	2640	3080	3520	3960	4400	4840	5280	6160	7040	7920	8800	9680	10560
0.80	469.	939	2816	3285	3755	4224	4693	5163	5632	6571	7509	8448	9387	10325	11264
0.85	499.	997	2992	3491	3989	4488	4987	5485	5984	6981	7979	8976	9973	10971	11968
0.90	528.	1056	3168	3696	4224	4752	5280	5808	6336	7392	8448	9504	10560	11616	12672
0.95	557.	1115	3344	3901	4459	5016	5573	6131	6688	7803	8917	10032	11147	12261	13376
1.00	587.	1173	3520	4107	4693	5280	5867	6453	7040	8213	9387	10560	11733	12907	14080
1.10	645.	1291	3872	4517	5163	5808	6453	7099	7744	9035	10325	11615	12907	14197	15488
1.20	704.	1408	4224	4928	5632	6336	7040	7744	8448	9856	11264	12672	14080	15488	16896
1.25	733.	1467	4400	5133	5867	6600	7333	8067	8800	10267	11733	13200	14667	16133	17600
1.30	763.	1525	4576	5339	6101	6864	7627	8389	9152	10677	12203	13728	15253	16779	18304
1.40	821.	1643	4928	5749	6571	7392	8213	9035	9856	11499	13141	14784	16427	16069	19712
1.50	880.	1760	5280	6160	7040	7920	8800	9680	10560	12320	14080	15840	17600	19360	21120
1.75	1027.	2053	6160	7187	8213	9240	10267	11293	12320	14373	16427	18480	20533	22587	24640
2.00	1173.	2347	7040	8213	9387	10560	11733	12907	14080	16427	18773	21120	23467	25813	28160
2.25	1320.	2640	7920	9240	10560	11880	13200	14520	15840	18480	21120	23760	26400	29040	31680
2.50	1467.	2933	8800	10267	11733	13200	14667	16133	17600	20533	23467	26400	29333	32267	35200
2.75	1613.	3227	9680	11293	12907	14520	16133	17747	19360	22587	25813	29040	32267	35493	38720
3.00	1760.	3520	10560	12320	14080	15840	17600	19360	21120	24640	28160	31680	35200	38720	42240

NOTE: Formula used for calculation:

$$Q = \frac{5280\ W}{9} R = 586.67\ WR$$

Where:
Q = Quantity of asphalt required, in gallons per mile
R = Rate of application, in gallons per sq. yd.
W = Width of application, in feet

TABLE I-4

LINEAR FEET COVERED BY 600-GALLON TANK OF ASPHALT FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	54000	27000	9000	7714	6750	6000	5400	4909	4500	3857	3375	3000	2700	2454	2250
0.15	36000	18000	6000	5143	4500	4000	3600	3272	3000	2571	2250	2000	1800	1636	1500
0.20	27000	13500	4500	3857	3375	3000	2700	2454	2250	1928	1687	1500	1350	1227	1125
0.25	21600	10800	3600	3086	2700	2400	2160	1963	1800	1543	1350	1200	1080	981	900
0.30	18000	9000	3000	2571	2250	2000	1800	1636	1500	1285	1125	1000	900	818	750
0.35	15429	7714	2572	2204	1928	1714	1543	1402	1286	1102	964	857	772	701	643
0.40	13500	6750	2250	1929	1688	1500	1350	1227	1125	964	844	750	675	613	562
0.45	12000	6000	2000	1714	1500	1333	1200	1091	1000	857	750	667	600	545	500
0.50	10800	5400	1800	1543	1350	1200	1080	982	900	771	675	600	540	491	450
0.55	9818	4909	1636	1403	1227	1091	982	893	818	702	614	546	491	446	409
0.60	9000	4500	1500	1286	1125	1000	900	818	750	643	562	500	450	409	375
0.65	8308	4154	1385	1187	1038	923	831	755	692	593	519	461	415	377	346
0.70	7714	3857	1286	1102	964	857	771	701	643	551	482	428	366	350	321
0.75	7200	3600	1200	1029	900	800	720	655	600	514	450	400	360	327	300
0.80	6750	3375	1125	964	844	750	675	613	562	482	422	375	338	306	281
0.85	6353	3176	1059	908	794	706	635	577	529	454	397	353	317	288	265
0.90	6000	3000	1000	857	750	667	600	545	500	428	375	333	300	272	250
0.95	5684	2842	947	812	710	632	568	517	473	406	355	316	284	258	236
1.00	5400	2700	900	771	675	600	540	491	450	385	337	300	270	245	225
1.10	4909	2455	818	701	614	545	491	446	409	351	307	273	245	223	204
1.20	4500	2250	750	643	562	500	450	409	375	321	281	250	225	204	187
1.25	4320	2160	720	617	540	480	432	393	360	308	270	240	216	196	180
1.30	4154	2077	692	593	519	461	415	377	346	296	259	230	207	188	173
1.40	3857	1929	643	551	482	428	386	350	321	275	241	214	193	175	160
1.50	3600	1800	600	514	450	400	360	327	300	257	225	200	180	163	150
1.75	3086	1543	514	441	386	343	309	260	257	220	193	171	154	140	128
2.00	2700	1350	450	386	338	300	270	245	225	193	169	150	135	122	112
2.25	2400	1200	400	343	300	267	240	218	200	171	150	133	120	109	100
2.50	2160	1080	360	309	270	240	216	197	180	154	135	120	108	98	90
2.75	1964	982	327	281	246	218	196	179	164	140	123	109	98	89	82
3.00	1800	900	300	257	225	200	180	164	150	128	112	100	90	82	5

NOTE: See Table I-11 for formula used for calculation.

TABLE I-5

LINEAR FEET COVERED BY 800-GALLON TANK OF ASPHALT FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	72000	36000	12000	10286	9000	8000	7200	6545	6000	5143	4500	4000	3600	3272	3000
0.15	48000	24000	8000	6857	6000	5333	4800	4364	4000	3429	3000	2667	2400	2182	2000
0.20	36000	18000	6000	5143	4500	4000	3600	3273	3000	2571	2250	2000	1800	1636	1500
0.25	28800	14400	4800	4114	3600	3200	2880	2618	2400	2057	1800	1600	1440	1309	1200
0.30	24000	12000	4000	3429	3000	2667	2400	2182	2000	1714	1500	1333	1200	1091	1000
0.35	20571	10286	3429	2939	2571	2286	2057	1870	1714	1469	1286	1143	1029	935	857
0.40	18000	9000	3000	2571	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
0.45	16000	8000	2667	2286	2000	1778	1600	1455	1333	1143	1000	889	800	727	667
0.50	14400	7200	2400	2057	1800	1600	1440	1309	1200	1029	900	800	720	654	600
0.55	13091	6545	2182	1870	1636	1455	1309	1190	1091	935	818	727	654	595	545
0.60	12000	6000	2000	1714	1500	1333	1200	1091	1000	857	750	667	600	545	500
0.65	11077	5539	1846	1582	1385	1231	1108	1007	923	791	692	615	554	504	461
0.70	10286	5143	1714	1469	1286	1143	1029	935	857	735	643	571	514	467	428
0.75	9600	4800	1600	1371	1200	1067	960	873	800	686	600	533	480	436	400
0.80	9000	4500	1500	1286	1125	1000	900	818	750	643	563	500	450	409	375
0.85	8471	4235	1412	1210	1059	941	847	770	706	605	529	470	423	385	353
0.90	8000	4000	1333	1143	1000	889	800	727	667	571	500	444	400	363	333
0.95	7579	3789	1263	1083	947	842	758	689	632	541	473	421	379	344	316
1.00	7200	3600	1200	1029	900	800	720	655	600	514	450	400	360	327	300
1.10	6545	3272	1091	935	818	727	655	595	546	467	409	364	327	298	273
1.20	6000	3000	1000	857	750	667	600	545	500	428	375	333	300	273	250
1.25	5760	2880	960	823	720	640	576	524	480	411	360	320	288	262	240
1.30	5538	2769	923	791	692	615	554	504	461	395	346	307	277	252	230
1.40	5143	2571	857	735	643	571	514	468	428	367	321	285	257	234	214
1.50	4800	2400	800	686	600	533	480	436	400	343	300	267	240	218	200
1.75	4114	2057	686	588	514	457	411	374	343	294	257	229	206	187	171
2.00	3600	1800	600	514	450	400	360	327	300	257	225	200	180	163	150
2.25	3200	1600	533	457	400	356	320	291	267	229	200	178	160	145	133
2.50	2880	1440	480	411	360	320	288	262	240	206	180	160	144	131	120
2.75	2618	1309	436	374	327	291	262	238	218	187	163	145	131	119	109
3.00	2400	1200	400	343	300	267	240	218	200	171	150	133	120	109	100

NOTE: See Table 1-11 for formula used for calculation.

TABLE I-6

LINEAR FEET COVERED BY 1000-GALLON TANK OF ASPHALT FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	90000	45000	15000	12857	11250	10000	9000	8182	7500	6429	5625	5000	4500	4091	3750
0.15	60000	30000	10000	8571	7500	6667	6000	5455	5000	4286	3750	3333	3000	2727	2500
0.20	45000	22500	7500	6429	5625	5000	4500	4091	3750	3214	2813	2500	2250	2045	1875
0.25	36000	18000	6000	5143	4500	4000	3600	3273	3000	2571	2250	2000	1800	1636	1500
0.30	30000	15000	5000	4286	3750	3333	3000	2727	2500	2143	1875	1667	1500	1363	1250
0.35	25714	12857	4286	3673	3214	2857	2571	2338	2143	1837	1607	1429	1286	1169	1071
0.40	22500	11250	3750	3214	2813	2500	2250	2045	1875	1607	1406	1250	1125	1022	937
0.45	20000	10000	3333	2857	2500	2222	2000	1818	1667	1429	1250	1111	1000	909	833
0.50	18000	9000	3000	2571	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
0.55	16364	8182	2727	2338	2046	1818	1636	1488	1364	1169	1023	909	818	744	682
0.60	15000	7500	2500	2143	1875	1667	1500	1364	1250	1071	938	833	750	682	625
0.65	13846	6923	2308	1978	1731	1538	1385	1259	1154	989	865	769	692	629	577
0.70	12857	6429	2143	1837	1607	1429	1286	1169	1071	918	804	714	643	584	535
0.75	12000	6000	2000	1714	1500	1333	1200	1091	1000	857	750	667	600	545	500
0.80	11250	5625	1875	1607	1406	1250	1125	1023	938	804	703	625	563	511	469
0.85	10588	5294	1765	1513	1324	1176	1059	963	882	756	662	588	529	481	441
0.90	10000	5000	1667	1429	1250	1111	1000	909	833	714	625	556	500	454	416
0.95	9474	4737	1579	1353	1184	1053	947	861	789	676	592	526	473	430	394
1.00	9000	4500	1500	1286	1125	1000	900	818	750	643	563	500	450	409	375
1.10	8182	4091	1364	1169	1023	909	818	744	682	584	511	454	409	372	341
1.20	7500	3750	1250	1071	938	833	750	682	625	535	469	416	375	341	312
1.25	7200	3600	1200	1029	900	800	720	655	600	514	450	400	360	327	300
1.30	6923	3462	1154	989	866	769	692	629	577	494	433	384	346	314	288
1.40	6429	3215	1072	918	804	714	643	584	536	459	402	357	321	292	268
1.50	6000	3000	1000	857	750	667	600	545	500	429	375	333	300	272	250
1.75	5143	2571	857	735	643	571	514	468	429	367	321	286	257	234	214
2.00	4500	2250	750	643	563	500	450	409	375	321	281	250	225	204	187
2.25	4000	2000	667	571	500	444	400	364	333	286	250	222	200	182	166
2.50	3600	1800	600	514	450	400	360	327	300	257	225	200	180	163	150
2.75	3273	1636	545	468	409	364	327	298	272	234	204	182	163	149	136
3.00	3000	1500	500	429	375	333	300	273	250	214	187	167	150	136	125

NOTE: See Table 1-11 for formula used for calculation.

TABLE I-7

LINEAR FEET COVERED BY 1200-GALLON TANK OF ASPHALT FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	108000	54000	18000	15429	13500	12000	10800	9818	9000	7714	6750	6000	5400	4909	4500
0.15	72000	36000	12000	10286	9000	8000	7200	6545	6000	5143	4500	4000	3600	3272	3000
0.20	54000	27000	9000	7714	6750	6000	5400	4909	4500	3857	3375	3000	2700	2454	2250
0.25	43200	21600	7200	6171	5400	4800	4320	3927	3600	3086	2700	2400	2160	1963	1800
0.30	36000	18000	6000	5143	4500	4000	3600	3273	3000	2571	2250	2000	1800	1636	1500
0.35	30858	15429	5143	4408	3857	3429	3086	2805	2571	2204	1928	1714	1543	1402	1286
0.40	27000	13500	4500	3857	3375	3000	2700	2455	2250	1929	1688	1500	1350	1227	1125
0.45	24000	12000	4000	3429	3000	2667	2400	2182	2000	1714	1500	1333	1200	1091	1000
0.50	21600	10800	3600	3086	2700	2400	2160	1964	1800	1543	1350	1200	1080	982	900
0.55	19636	9818	3273	2805	2454	2182	1965	1786	1636	1403	1227	1091	982	893	818
0.60	18000	9000	3000	2571	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
0.65	16616	8308	2769	2374	2077	1846	1662	1510	1385	1187	1038	923	831	755	692
0.70	15428	7714	2571	2204	1929	1714	1543	1403	1286	1102	964	857	771	701	643
0.75	14400	7200	2400	2057	1800	1600	1440	1309	1200	1029	900	800	720	655	600
0.80	13500	6750	2250	1929	1688	1500	1350	1227	1125	964	844	750	675	613	562
0.85	12706	6353	2118	1815	1588	1412	1271	1154	1059	908	794	706	635	577	529
0.90	12000	6000	2000	1714	1500	1333	1200	1091	1000	857	750	667	600	545	500
0.95	11368	5684	1895	1624	1421	1263	1137	1034	947	812	710	632	568	517	473
1.00	10800	5400	1800	1543	1350	1200	1080	982	900	771	675	600	540	491	450
1.10	9818	4909	1636	1403	1227	1091	982	893	818	701	614	545	491	446	409
1.20	9000	4500	1500	1286	1125	1000	900	818	750	643	562	500	450	409	375
1.25	8640	4320	1440	1234	1080	960	864	785	720	617	540	480	432	393	360
1.30	8308	4154	1385	1187	1038	923	831	755	692	593	519	461	415	377	346
1.40	7714	3857	1286	1102	964	857	771	701	643	551	482	428	386	350	321
1.50	7200	3600	1200	1029	900	800	720	655	600	514	450	400	360	327	300
1.75	6172	3086	1029	882	771	686	617	561	514	441	386	343	309	280	257
2.00	5400	2700	900	771	675	600	540	491	450	386	338	300	270	245	225
2.25	4800	2400	800	686	600	533	480	436	400	343	300	267	240	218	200
2.50	4320	2160	720	617	540	480	432	393	360	309	270	240	216	197	180
2.75	3927	1964	655	561	491	436	393	357	327	281	246	218	196	179	164
3.00	3600	1800	600	514	450	400	360	327	300	257	225	200	180	164	150

NOTE: See Table 1-11 for formula used for calculation

TABLE I-8

LINEAR FEET COVERED BY 1500-GALLON TANK OF ASPHALT FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	135000	67500	22500	19286	16875	15000	13500	12273	11250	9643	8438	7500	6750	6136	5625
0.15	90000	45000	15000	12857	11250	10000	9000	8182	7500	6428	5625	5000	4500	4091	3750
0.20	67500	33750	11250	9643	8438	7500	6750	6136	5625	4821	4219	3750	3375	3068	2812
0.25	54000	27000	9000	7714	6750	6000	5400	4909	4500	3857	3375	3000	2700	2454	2250
0.30	45000	22500	7500	6429	5625	5000	4500	4091	3750	3214	2812	2500	2250	2045	1875
0.35	38571	19286	6429	5510	4822	4286	3857	3507	3214	2755	2411	2143	1929	1754	1607
0.40	33750	16875	5625	4821	4219	3750	3375	3068	2812	2410	2110	1875	1688	1534	1406
0.45	30000	15000	5000	4286	3750	3333	3000	2727	2500	2143	1875	1667	1500	1364	1250
0.50	27000	13500	4500	3857	3375	3000	2700	2455	2250	1928	1688	1500	1350	1227	1125
0.55	24545	12273	4091	3507	3068	2727	2455	2231	2045	1754	1531	1364	1227	1116	1023
0.60	22500	11250	3750	3214	2812	2500	2250	2045	1875	1607	140	1250	1125	1022	938
0.65	20769	10385	3462	2967	2596	2308	2077	1888	1731	1484	1298	1154	1038	944	865
0.70	19286	9643	3214	2755	2411	2143	1929	1753	1607	1378	1206	1072	964	877	804
0.75	18000	9000	3000	2571	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
0.80	16875	8437	2812	2411	2109	1875	1688	1534	1406	1205	1055	938	844	767	703
0.85	15882	7941	2647	2269	1985	1765	1588	1444	1324	1134	992	882	794	722	662
0.90	15000	7500	2500	2143	1875	1667	1500	1364	1250	1071	938	834	750	682	625
0.95	14210	7105	2368	2030	1776	1579	1421	1292	1184	1015	888	790	710	646	592
1.00	13500	6750	2250	1929	1688	1500	1350	1227	1125	964	844	750	675	614	562
1.10	12273	6136	2045	1753	1535	1364	1227	1116	1022	877	768	682	614	558	511
1.20	11250	5625	1875	1607	1406	1250	1125	1023	938	803	703	625	562	511	469
1.25	10800	5400	1800	1543	1350	1200	1080	982	900	771	675	600	540	491	450
1.30	10385	5192	1731	1484	1298	1154	1038	944	866	742	649	577	519	472	433
1.40	9643	4821	1607	1378	1205	1071	964	877	804	689	603	536	482	438	402
1.50	9000	4500	1500	1286	1125	1000	900	818	750	643	562	500	450	409	375
1.75	7714	3857	1286	1102	964	857	771	701	643	551	482	429	386	351	321
2.00	6750	3375	1125	964	844	750	675	614	562	482	422	375	338	307	281
2.25	6000	3000	1000	857	750	667	600	545	500	429	375	334	300	273	250
2.50	5400	2700	900	771	675	600	540	491	450	385	338	300	270	246	225
2.75	4909	2455	818	701	614	545	491	446	409	351	307	273	245	223	205
3.00	4500	2250	750	643	562	500	450	409	375	321	281	250	225	204	188

NOTE: See Table 1-11 for formula used for calculation.

TABLE I-9

LINEAR FEET COVERED BY 2000-GALLON TANK OF ASPHALT FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	180000	90000	30000	25714	22500	20000	18000	16364	15000	12857	11250	10000	9000	8182	7500
0.15	120000	60000	20000	17142	15000	13333	12000	10910	10000	8571	7500	6667	6000	5455	5000
0.20	90000	45000	15000	12857	11250	10000	9000	8182	7500	6429	5625	5000	4500	4091	3750
0.25	72000	36000	12000	10286	9000	8000	7200	6546	6000	5143	4500	4000	3600	3273	3000
0.30	60000	30000	10000	8571	7500	6667	6000	5455	5000	4286	3750	3333	3000	2727	2500
0.35	51428	25714	8571	7346	6428	5714	5143	4676	4286	3673	3214	2857	2571	2338	2143
0.40	45000	22500	7500	6428	5625	5000	4500	4091	3750	3214	2813	2500	2250	2045	1875
0.45	40000	20000	6667	5714	5000	4444	4000	3637	3333	2857	2500	2222	2000	1818	1667
0.50	36000	18000	6000	5143	4500	4000	3600	3273	3000	2571	2250	2000	1800	1636	1500
0.55	32728	16364	5455	4676	4091	3636	3273	2976	2727	2338	2046	1818	1636	1488	1364
0.60	30000	15000	5000	4286	3750	3333	3000	2728	2500	2143	1875	1667	1500	1364	1250
0.65	27692	13846	4615	3956	3462	3077	2769	2518	2308	1978	1731	1538	1385	1259	1154
0.70	25714	12857	4286	3673	3214	2857	2571	2338	2143	1837	1607	1429	1286	1169	1071
0.75	24000	12000	4000	3429	3000	2667	2400	2182	2000	1714	1500	1333	1200	1091	1000
0.80	22500	11250	3750	3214	2812	2500	2250	2046	1875	1607	1406	1250	1125	1023	938
0.85	21176	10588	3529	3026	2647	2353	2118	1926	1765	1513	1324	1176	1059	963	882
0.90	20000	10000	3333	2857	2500	2222	2000	1818	1667	1429	1250	1111	1000	909	833
0.95	18946	9474	3158	2706	2368	2105	1895	1722	1579	1353	1184	1053	947	861	789
1.00	18000	9000	3000	2572	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
1.10	16364	8182	2727	2338	2046	1818	1636	1488	1364	1169	1023	909	818	744	682
1.20	15000	7500	2500	2143	1875	1667	1500	1364	1250	1071	938	833	750	682	625
1.25	14400	7200	2400	2057	1800	1600	1440	1309	1200	1029	900	800	720	655	600
1.30	13848	6923	2303	1978	1732	1538	1385	1259	1154	989	866	769	692	629	577
1.40	12858	6429	2143	1836	1607	1428	1286	1169	1072	918	804	714	643	584	536
1.50	12000	6000	2000	1714	1500	1333	1200	1091	1000	857	750	667	600	545	500
1.75	10286	5143	1714	1469	1286	1143	1029	935	857	735	643	571	514	467	429
2.00	9000	4500	1500	1286	1125	1000	900	818	750	643	563	500	450	409	375
2.25	8000	4000	1333	1143	1000	889	800	727	667	571	500	444	400	364	333
2.50	7200	3600	1200	1028	900	800	720	654	600	514	450	400	360	327	300
2.75	6546	3273	1091	935	818	727	655	595	545	468	409	364	327	298	272
3.00	6000	3000	1000	857	750	667	600	545	500	429	375	333	300	273	250

NOTE: See Table 1-11 for formula used for calculation.

TABLE I-10

LINEAR FEET COVERED BY 2500-GALLON TANK OF ASPHALT FOR VARIOUS WIDTHS AND GALLONS PER SQUARE YARD

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	225000	112500	37500	32143	28125	25000	22500	20455	18750	16072	14062	12500	11250	10227	9375
0.15	150000	75000	25000	21429	18750	16667	15000	13637	12500	10714	9375	8333	7500	6818	6250
0.20	112500	56250	18750	16071	14062	12500	11250	10227	9375	8036	7031	6250	5625	5113	4687
0.25	90000	45000	15000	12857	11250	10000	9000	8182	7500	6428	5625	5000	4500	4091	3750
0.30	75000	37500	12500	10714	9375	8333	7500	6818	6250	5357	4688	4167	3750	3409	3125
0.35	64286	32143	10714	9184	8036	7143	6429	5844	5357	4592	4018	3571	3214	2922	2678
0.40	56250	28125	9375	8036	7031	6250	5625	5114	4688	4018	3515	3125	2812	2557	2344
0.45	50000	25000	8333	7143	6250	5556	5000	4546	4166	3571	3125	2778	2500	2273	2083
0.50	45000	22500	7500	6429	5625	5000	4500	4091	3750	3214	2812	2500	2250	2045	1875
0.55	40909	20455	6818	5844	5114	4545	4091	3719	3409	2922	2557	2273	2045	1859	1704
0.60	37500	18750	6250	5357	4688	4167	3750	3409	3125	2678	2344	2083	1875	1704	1562
0.65	34615	17308	5769	4945	4327	3846	3462	3147	2884	2472	2163	1923	1731	1573	1442
0.70	32143	16071	5357	4592	4018	3571	3214	2922	2678	2296	2009	1785	1607	1461	1339
0.75	30000	15000	5000	4286	3750	3333	3000	2727	2500	2143	1875	1667	1500	1363	1250
0.80	28125	14062	4687	4018	3516	3125	2812	2557	2344	2009	1758	1562	1406	1278	1172
0.85	26471	13235	4412	3782	3309	2941	2647	2406	2206	1891	1654	1470	1323	1203	1103
0.90	25000	12500	4167	3571	3125	2778	2500	2273	2083	1786	1562	1389	1250	1136	1041
0.95	23684	11842	3947	3383	2960	2632	2368	2153	1974	1692	1480	1316	1184	1076	987
1.00	22500	11250	3750	3214	2812	2500	2250	2046	1875	1607	1406	1250	1125	1023	937
1.10	20455	10228	3409	2922	2557	2273	2046	1860	1704	1461	1278	1136	1023	930	852
1.20	18750	9375	3125	2679	2344	2083	1875	1705	1562	1339	1172	1041	937	852	781
1.25	18000	9000	3000	2571	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
1.30	17308	8654	2885	2473	2164	1923	1731	1573	1442	1236	1082	961	865	786	721
1.40	16071	8036	2679	2296	2009	1786	1607	1461	1339	1148	1004	893	804	730	669
1.50	15000	7500	2500	2143	1875	1667	1500	1364	1250	1071	937	833	750	682	625
1.75	12857	6429	2143	1837	1607	1429	1286	1169	1071	918	803	714	643	584	536
2.00	11250	5625	1875	1607	1406	1250	1125	1023	938	803	703	625	562	511	469
2.25	10000	5000	1667	1429	1250	1111	1000	909	833	714	625	556	500	454	417
2.50	9000	4500	1500	1286	1125	1000	900	818	750	643	562	500	450	409	375
2.75	8182	4091	1364	1169	1023	909	818	744	682	584	511	454	409	372	341
3.00	7500	3750	1250	1071	938	833	750	682	625	535	469	417	375	341	312

NOTE: See Table 1-11 for formula used for calculation.

TABLE I-11

LINEAR FEET COVERED BY TANK OF ANY CAPACITY FOR VARIOUS WIDTHS AND GALLONS PER SQ YD

To compute the number of linear feet which will be covered by a tank of any capacity, for various widths and rates of application, use the following formula:

$$L = \frac{9C}{RW}$$

Where:

L = No. of linear feet which will be covered
C = Capacity of tank in gallons (or quantity of asphalt in tank)
R = Rate of application in gallons per sq yd
W = Width of application in feet

Note:

In many instances it will be easier to make such computations from data contained in Tables 1-4 to 1-10, using appropriate multiplying factors. For example, it is apparent that the number of linear feet covered by a 4000-gallon tank, for a given width, would be twice that covered by a 2000-gallon tank for the same width. If the tank capacity is not in some convenient multiple, such as a 3300-gallon tank, the data contained in Table 1-6 for the 1000-gallon tank may be multiplied by an appropriate factor. For the 3300-gallon tank, the multiplying factor would be 3300 ÷ 1000 = 3.3. An example of such a computation for the 3300-gallon tank is as follows:

1. Table 1-6 indicates that a 1000-gallon tank will cover 3000 linear feet when applied to a strip 12 feet wide and at a rate of 0.20 gallons per sq yd
2. A 3300-gallon tank would cover 3.3 times this distance or 3.3 × 3000 = 9900 linear feet

TABLE I-12

QUANTITIES FOR VARIOUS DEPTHS OF CYLINDRICAL TANKS IN HORIZONTAL POSITION

% Depth Filled	% of Capacity	% Depth Filled	% of Capacity	% Depth Filled	% of Capacity	% Depth Filled	% of Capacity
1	0.20	26	20.73	51	51.27	76	81.50
2	0.50	27	21.86	52	52.55	77	82.60
3	0.90	28	23.00	53	53.81	78	83.68
4	1.34	29	24.07	54	55.08	79	84.74
5	1.87	30	25.31	55	56.34	80	85.77
6	2.45	31	26.48	56	57.60	81	86.77
7	3.07	32	27.66	57	58.86	82	87.76
8	3.74	33	28.84	58	60.11	83	88.73
9	4.45	34	30.03	59	61.36	84	89.68
10	5.20	35	31.19	60	62.61	85	90.60
11	5.98	36	32.44	61	63.86	86	91.50
12	6.80	37	33.66	62	65.10	87	92.36
13	7.64	38	34.90	63	66.34	88	93.20
14	8.50	39	36.14	64	67.56	89	94.02
15	9.40	40	37.39	65	68.81	90	94.80
16	10.32	41	38.64	66	69.97	91	95.55
17	11.27	42	39.89	67	71.16	92	96.26
18	12.24	43	41.14	68	72.34	93	96.93
19	13.23	44	42.40	69	73.52	94	97.55
20	14.23	45	43.66	70	74.69	95	98.13
21	15.26	46	44.92	71	75.93	96	98.66
22	16.32	47	46.19	72	77.00	97	99.10
23	17.40	48	47.45	73	78.14	98	99.50
24	18.50	49	48.73	74	79.27	99	99.80
25	19.61	50	50.00	75	80.39		

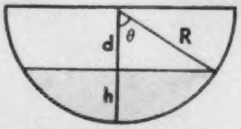
Full capacity of tank in U. S. gallons $= \frac{0.7854 \times D^2 \times L}{231}$

Note: The formula for direct computation of quantity when tank is less than half full is shown below. When more than half full, compute the full capacity of the tank as noted above; consider the shaded portion to represent the unfilled portion at the top of the tank and compute its volume as indicated below; then, deduct the volume determined for the unfilled portion from the total volume of the tank to arrive at the volume of the filled portion.

First, compute θ where $\cos\theta = \frac{d}{R} = \frac{R-h}{R}$

Then $A = \pi R^2 \frac{\theta}{180} - R \sin\theta\,(R - h)$

And $V = \frac{R\left[\pi R^2 \frac{\theta}{180} - R \sin\theta\,(R-h)\right]}{231}$



Where A = Cross section area of filled portion of tank in sq in
V = Volume of filled portion of tank in U.S. gallons
L = Length of interior of tank in inches
D = Diameter of interior of tank in inches
R = Radius of interior of tank in inches
h = Depth of liquid in inches
d = R − h, inches

Note: The volume occupied by any piping, fittings or other material inside the tank must be deducted from the volume computed by use of the table or formula.

TABLE I-13

WEIGHT PER CUBIC FOOT AND PER CUBIC YARD OF DRY MINERAL AGGREGATES FOR AGGREGATES OF DIFFERENT SPECIFIC GRAVITY AND VARIOUS VOID CONTENTS

	Specific Gravity	VOIDS—PERCENT								
		15	20	25	30	35	40	45	50	55
POUNDS PER CUBIC FOOT	2.0	106.1	99.8	93.6	87.4	81.1	74.9	68.6	62.4	56.2
	2.1	111.4	104.8	98.3	91.7	85.2	78.6	72.1	65.5	59.0
	2.2	116.7	109.8	103.0	96.1	89.2	82.4	75.5	68.6	61.8
	2.3	122.0	114.8	107.6	100.5	93.3	86.1	78.9	71.8	64.6
	2.4	127.3	119.8	112.3	104.8	97.3	89.9	82.4	74.9	67.4
	2.5	132.6	124.8	117.0	109.2	101.4	93.6	85.8	78.0	70.2
	2.6	137.9	129.8	121.7	113.6	105.5	97.3	89.2	81.1	73.0
	2.7	143.2	134.8	126.4	117.9	109.5	101.1	92.7	84.2	75.8
	2.8	148.5	139.8	131.0	122.3	113.6	104.8	96.1	87.4	78.6
	2.9	153.8	144.8	135.7	126.7	117.6	108.6	99.5	90.5	81.4
	3.0	159.1	149.8	140.4	131.0	121.7	112.3	103.0	93.6	84.2
	3.1	164.4	154.8	145.1	135.4	125.7	116.1	106.4	96.7	87.0
	3.2	169.7	159.7	149.8	139.8	129.8	119.8	109.8	99.8	89.9
POUNDS PER CUBIC YARD	2.0	2860	2700	2530	2360	2190	2020	1850	1680	1520
	2.1	3010	2830	2650	2480	2300	2120	1950	1770	1590
	2.2	3150	2970	2780	2590	2410	2220	2040	1850	1670
	2.3	3290	3100	2910	2710	2520	2330	2130	1940	1740
	2.4	3440	3240	3030	2830	2630	2430	2220	2020	1820
	2.5	3580	3370	3160	2950	2740	2530	2320	2110	1900
	2.6	3720	3500	3290	3070	2850	2630	2410	2190	1970
	2.7	3870	3640	3410	3180	2960	2730	2500	2270	2050
	2.8	4010	3770	3540	3300	3070	2830	2590	2360	2120
	2.9	4150	3910	3660	3420	3180	2930	2690	2440	2200
	3.0	4300	4040	3790	3540	3290	3030	2780	2530	2270
	3.1	4440	4180	3920	3660	3400	3130	2870	2610	2350
	3.2	4580	4310	4040	3770	3500	3230	2970	2700	2430

1. The Specific Gravity of commonly used road construction aggregates normally is within the following ranges:

Granite	2.6-2.9	Sand (Quartzite)	2.5-2.7	Blast Furnace Slag	2:0-2.5
Gravel	2.5-2.7	Sandstone	2.0-2.7		
Limestone	2.1-2.8	Traprock	2.7-3.2		

2. Data contained in this table are applicable to dry mineral aggregates in either the loose or compacted state, and the void content should be selected accordingly. Preferably, both the void content and specific gravity should be determined in the laboratory.
3. The formulas for computation of data in table above are as follows:

Per Cu Ft

$$W = 62.4 \times \frac{G(100 - v)}{100} = 0.624\, G(100 - v)$$

and

Per Cu Yd

$$W = 27 \times 62.4 \times \frac{G(100 - v)}{100} = 16.85\, G(100 - v)$$

Where:
W = Wt. per cu ft
W = Wt. per cu yd
G = Specific gravity
V = Air void content, percent

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TABLE I-14

WEIGHT AND VOLUME RELATIONS FOR VARIOUS TYPES OF COMPACTED ASPHALT PAVEMENTS

Note:

Because of the considerable variations of specific gravity, gradation, and other characteristics of mineral aggregates, weight per unit volume of compacted asphalt pavement varies considerably. Exact weights per unit volume should be determined in the laboratory from samples taken from the pavement or prepared in the laboratory with the same materials as used in the field.

Pounds Per Cubic Foot	Pounds Per Cubic Yard	Pounds Per Square Yard Per 1 Inch Depth
100	2700	75
105	2835	79
110	2970	82
115	3105	86
120	3240	90
125	3375	94
130	3510	97
135	3645	101
140	3780	105
145	3915	109
150	4050	112
155	4185	116
160	4320	120

	Range	Range	Range	Frequently Used for Preliminary Estimate
Macadam—A.I. Type I or Penetration Macadam	110–135	2970–3645	82–101	95
Open Graded—A.I. Type II	115–140	3105–3780	86–105	100
Coarse Graded—A.I. Type III	130–150	3510–4050	97–112	105
Dense Graded—A.I. Type IV	135–155	3645–4185	101–116	110
Fine Graded—A.I. Type V	130–150	3510–4050	97–112	105
Stone Sheet—A.I. Type VI	130–150	3510–4050	97–112	105
Sand Sheet—A.I. Type VII	120–140	3240–3780	90–105	100
Fine Sheet—A.I. Type VIII	120–140	3240–3780	90–105	100
Mixed-In-Place Macadam—A.I. Spec. RM–1	110–135	2970–3645	82–101	95
Mixed-In-Place Dense Graded—A.I. Spec. RM–2	110–135	2970–3645	82–101	95
Mixed-In-Place Sand Asphalt—A.I. Spec. RM–3	100–125	2700–3375	75–94	85

TABLE I-15

POUNDS PER SQUARE YARD OF MATERIAL REQUIRED FOR VARIOUS DEPTHS AND WEIGHTS OF MATERIALS IN POUNDS PER CUBIC YARD

Lbs Per Cu Yd	Depth—Inches											
	1	2	3	4	5	6	7	8	9	10	11	12
10	0.3	0.6	0.8	1.1	1.4	1.7	1.9	2.2	2.5	2.8	3.1	3.3
20	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.6	6.1	6.7
30	0.8	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0
40	1.1	2.2	3.3	4.4	5.6	6.7	7.8	8.9	10.0	11.1	12.2	13.3
50	1.4	2.8	4.2	5.6	6.9	8.3	9.7	11.1	12.5	13.9	15.3	16.7
60	1.7	3.3	5.0	6.7	8.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0
70	1.9	3.9	5.8	7.8	9.7	11.7	13.6	15.6	17.5	19.4	21.4	23.3
80	2.2	4.4	6.7	8.9	11.1	13.3	15.6	17.8	20.0	22.2	24.4	26.7
90	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
100	2.8	5.6	8.3	11.1	13.9	16.6	19.4	22.2	25.0	27.8	30.5	33.3
200	5.6	11.1	16.7	22.2	27.8	33.3	38.9	44.4	50.0	55.5	61.1	66.6
300	8.3	16.7	25.0	33.3	41.7	50.0	58.3	66.6	75.0	83.3	91.6	100.0
400	11.1	22.2	33.3	44.4	55.5	66.6	77.8	88.9	100.0	111.1	122.2	133.3
500	13.9	27.8	41.7	55.5	69.4	83.3	97.2	111.1	125.0	138.8	152.7	166.6
600	16.7	33.3	50.0	66.6	83.3	100.0	116.6	133.3	150.0	166.6	183.3	199.9
700	19.4	38.9	58.3	77.8	97.2	116.6	136.1	155.5	175.0	194.4	213.8	233.3
800	22.2	44.4	66.6	88.9	111.1	133.3	155.5	177.7	199.9	222.2	244.4	266.6
900	25.0	50.0	75.0	100.0	125.0	150.0	175.0	200.0	224.9	250.0	274.9	299.9
1000	27.8	55.5	83.3	111.1	138.8	166.6	194.4	222.2	249.9	277.7	305.5	333.2
2000	55.5	111.1	166.6	222.2	277.7	333.2	388.8	444.3	499.9	555.4	610.9	666.5
3000	83.3	166.6	250.0	333.2	416.6	500.0	583.2	666.5	749.8	833.1	916.4	999.7
4000	111.1	222.2	333.2	444.3	555.4	666.5	777.6	888.6	999.7	1110.8	1221.9	1333.0
5000	138.8	277.7	416.6	555.4	694.2	833.1	972.0	1110.8	1249.6	1388.5	1527.4	1666.2

Note: Formula used for calculations: $q = \frac{(D)}{(36)} W = 0.02777\ D\ W$

Where:
q = Quantity of material in lbs per sq yd
D = Depth in inches
W = Weight of material in lbs per cu yd

TABLE I-16

TONS OF MATERIAL REQUIRED PER 100 LINEAR FEET FOR VARIOUS WIDTHS AND POUNDS PER SQUARE YARD

Lbs Per Sq Yd	Width—Feet														
	1	2	3	4	5	6	7	8	9	10	20	30	40	50	60
1	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.11	0.17	0.22	0.28	0.33
2	0.01	0.02	0.03	0.04	0.06	0.07	0.08	0.09	0.10	0.11	0.22	0.33	0.44	0.56	0.67
3	0.02	0.03	0.05	0.07	0.08	0.10	0.12	0.13	0.15	0.17	0.33	0.50	0.67	0.83	1.00
4	0.02	0.04	0.07	0.09	0.11	0.13	0.16	0.18	0.20	0.22	0.44	0.67	0.89	1.11	1.33
5	0.03	0.06	0.08	0.11	0.14	0.17	0.19	0.22	0.25	0.28	0.56	0.83	1.11	1.39	1.67
6	0.03	0.07	0.10	0.13	0.17	0.20	0.23	0.27	0.30	0.33	0.67	1.00	1.33	1.67	2.00
7	0.04	0.08	0.12	0.16	0.19	0.23	0.27	0.31	0.35	0.39	0.78	1.17	1.56	1.94	2.33
8	0.04	0.09	0.13	0.18	0.22	0.27	0.31	0.36	0.40	0.44	0.89	1.33	1.78	2.22	2.67
9	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	1.00	1.50	2.00	2.50	3.00
10	0.06	0.11	0.17	0.22	0.28	0.33	0.39	0.44	0.50	0.56	1.11	1.67	2.22	2.78	3.33
20	0.11	0.22	0.33	0.44	0.56	0.67	0.78	0.89	1.00	1.11	2.22	3.33	4.44	5.56	6.67
30	0.17	0.33	0.50	0.67	0.83	1.00	1.17	1.33	1.50	1.67	3.33	5.00	6.67	8.33	10.00
40	0.22	0.44	0.67	0.89	1.11	1.33	1.56	1.78	2.00	2.22	4.44	6.67	8.89	11.11	13.33
50	0.28	0.56	0.83	1.11	1.39	1.67	1.94	2.22	2.50	2.78	5.56	8.33	11.11	13.89	16.67
60	0.33	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	6.67	10.00	13.33	16.67	20.00
70	0.39	0.78	1.17	1.56	1.94	2.33	2.72	3.11	3.50	3.89	7.78	11.67	15.56	19.44	23.33
80	0.44	0.89	1.33	1.78	2.22	2.67	3.11	5.56	4.00	4.44	8.89	13.33	17.78	22.22	26.67
90	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	10.00	15.00	20.00	25.00	30.00
100	0.56	1.11	1.67	2.22	2.78	3.33	3.89	4.44	5.00	5.56	11.11	16.67	22.22	27.78	33.33
200	1.11	2.22	3.33	4.44	5.56	6.67	7.78	8.89	10.00	11.11	22.22	33.33	44.44	55.56	66.67
300	1.67	3.33	5.00	6.67	8.33	10.00	11.67	13.33	15.00	16.67	33.33	50.00	66.67	83.33	100.00
400	2.22	4.44	6.67	8.89	11.11	13.33	15.56	17.78	20.00	22.22	44.44	66.67	88.89	111.11	133.33
500	2.78	5.56	8.33	11.11	13.89	16.67	19.44	22.22	25.00	27.78	55.56	83.33	111.11	138.89	166.67
600	3.33	6.67	10.00	13.33	16.67	20.00	23.33	26.67	30.00	33.33	66.67	100.00	133.33	166.67	200.00
700	3.89	7.78	11.67	15.56	19.44	23.33	27.22	31.11	35.00	38.89	77.78	116.69	155.56	194.44	233.33
800	4.44	8.89	13.33	17.78	22.22	26.67	31.11	35.56	40.00	44.44	88.89	133.33	177.78	222.22	266.67
900	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	100.00	150.00	200.00	250.00	300.00
1000	5.56	11.11	16.67	22.22	27.78	33.33	38.89	44.44	50.00	55.56	111.11	166.67	222.22	277.78	333.33

Note: Formula used for calculation:

$$w = \left(\frac{W}{3}\right)\left(\frac{100}{3}\right)\left(\frac{R}{2000}\right) = 0.005556\ RW$$

Where w = Weight of material in tons per 100 feet
R = Rate of application in lbs per sq yd
W = Width of application in feet

TABLE I-17

TONS OF MATERIAL REQUIRED PER MILE FOR VARIOUS WIDTHS AND POUNDS PER SQUARE YARD

Lbs Per Sq Yd	Width—Feet														
	1	2	3	4	5	6	7	8	9	10	20	30	40	50	60
1	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.3	2.6	2.9	5.9	8.8	11.7	14.7	17.6
2	0.6	1.2	1.8	2.3	2.9	3.5	4.1	4.7	5.3	5.9	11.7	17.6	23.5	29.3	35.2
3	0.9	1.8	2.6	3.5	4.4	5.3	6.2	7.0	7.9	8.8	17.6	26.4	35.2	44.0	52.8
4	1.2	2.3	3.5	4.7	5.9	7.0	8.2	9.4	10.6	11.7	23.5	35.2	46.9	58.7	70.4
5	1.5	2.9	4.4	5.9	7.3	8.8	10.3	11.7	13.2	14.7	29.3	44.0	58.7	73.3	88.0
6	1.8	3.5	5.3	7.0	8.8	10.6	12.3	14.1	15.8	17.6	35.2	52.8	70.4	88.0	105.6
7	2.1	4.1	6.2	8.2	10.3	12.3	14.4	16.4	18.5	20.5	41.1	61.6	82.1	102.7	123.2
8	2.3	4.7	7.0	9.4	11.7	14.1	16.4	18.8	21.1	23.5	46.9	70.4	93.9	117.3	140.8
9	2.6	5.3	7.9	10.6	13.2	15.8	18.5	21.1	23.8	26.4	52.8	79.2	105.6	132.0	158.4
10	2.9	5.9	8.8	11.7	14.7	17.6	20.5	23.5	26.4	29.3	58.7	88.0	117.3	146.7	176.0
20	5.9	11.7	17.6	23.5	29.3	35.2	41.1	46.9	52.8	58.7	117.3	176.0	234.7	293.3	352.0
30	8.8	17.6	26.4	35.2	44.0	52.8	61.6	70.4	79.2	88.0	176.0	264.0	352.0	440.0	527.9
40	11.7	23.5	35.2	46.9	58.7	70.4	82.1	93.9	105.6	117.3	234.7	352.0	469.3	586.7	704.0
50	14.7	29.3	44.0	58.7	73.3	88.0	102.7	117.3	132.0	146.7	293.3	440.0	586.7	733.3	880.0
60	17.6	35.2	52.8	70.4	88.0	105.6	123.2	140.8	158.4	176.0	352.0	528.0	704.0	880.0	1056.0
70	20.5	41.1	61.6	82.1	102.7	123.2	143.7	164.3	184.8	205.3	410.7	616.0	821.3	1026.7	1232.0
80	23.5	46.9	70.4	93.9	117.3	140.8	164.3	187.7	211.2	234.7	469.3	704.0	938.7	1173.3	1408.0
90	26.4	52.8	79.2	105.6	132.0	158.4	184.8	211.2	237.6	264.0	528.0	792.0	1056.0	1320.0	1584.0
100	29.3	58.7	88.0	117.3	146.7	176.0	205.3	234.7	264.0	293.3	586.7	880.0	1173.3	1466.7	1760.0
200	58.7	117.3	176.0	234.7	293.3	352.0	410.7	469.3	528.0	586.7	1173.3	1760.0	2346.7	2933.3	3520.0
300	88.0	176.0	264.0	352.0	440.0	528.0	616.0	704.0	792.0	880.0	1760.0	2640.0	3520.0	4400.0	5280.0
400	117.3	234.7	352.0	469.3	586.7	704.0	821.3	938.7	1056.0	1173.3	2346.7	3520.0	4693.3	5866.7	7040.0
500	146.7	293.3	440.0	586.7	733.3	880.0	1026.7	1173.3	1320.0	1466.7	2933.3	4400.0	5866.7	7333.3	8800.0
600	176.0	352.0	528.0	704.0	880.0	1056.0	1232.0	1408.0	1584.0	1760.0	3520.0	5280.0	7040.0	8800.0	10560.0
700	205.3	410.7	616.0	821.3	1026.7	1232.0	1437.3	1642.7	1848.0	2053.3	4106.7	6160.0	8213.3	10266.7	12320.0
800	234.7	469.3	704.0	938.7	1173.3	1408.0	1642.7	1877.3	2112.0	2346.7	4693.3	7040.0	9386.7	11733.3	14080.0
900	264.0	528.0	792.0	1056.0	1320.0	1584.0	1848.0	2112.0	2376.0	2640.0	5280.0	7920.0	10560.0	13200.0	15840.0
1000	293.3	586.7	880.0	1173.3	1466.7	1760.0	2053.3	2346.7	2640.0	2933.3	5866.7	8800.0	11733.3	14666.7	17600.0

Note: Formula used for calculation is as follows:

$$w = \left(\frac{W}{3}\right)\left(\frac{5280}{3}\right)\left(\frac{R}{2000}\right) = 0.2933\ RW$$

Where w = Weight of material in tons per mile
R = Rate of application in lbs per sq yd
W = Width of application in feet

TABLE I-18

LINEAR FEET COVERED BY ONE TON OF MATERIAL FOR VARIOUS WIDTHS AND POUNDS PER SQUARE YARD

Lbs Per Sq·Yd	Width—Feet									
	8	9	10	11	12	13	14	15	16	17
4	563	500	450	409	375	346	321	300	281	265
6	375	333	300	273	250	231	214	200	188	176
8	281	250	225	205	188	173	161	150	141	132
10	225	200	180	164	150	138	129	120	113	106
15	150	133	120	109	100	92.3	85.7	80.0	75.0	70.6
20	113	100	90.0	81.8	75.0	69.2	64.3	60.0	56.3	52.9
25	90.0	80.0	72.0	65.5	60.0	55.4	51.4	48.0	45.0	42.4
30	75.0	66.7	60.0	54.5	50.0	46.2	42.9	40.0	37.5	35.3
35	64.3	57.1	51.4	46.8	42.9	39.6	36.7	34.3	32.1	30.3
40	56.3	50.0	45.0	40.9	37.5	34.6	32.1	30.0	28.1	26.5
45	50.0	44.4	40.0	36.4	33.3	30.8	28.6	26.7	25.0	23.5
50	45.0	40.0	36.0	32.7	30.0	27.7	25.7	24.0	22.5	21.2
60	37.5	33.3	30.0	27.3	25.0	23.1	21.4	20.0	18.8	17.6
70	32.1	28.6	25.7	23.4	21.4	19.8	18.4	17.1	16.1	15.1
80	28.1	25.0	22.5	20.5	18.8	17.3	16.1	15.0	14.1	13.2
90	25.0	22.2	20.0	18.2	16.7	15.4	14.3	13.3	12.5	11.8
100	22.5	20.0	18.0	16.4	15.0	13.8	12.9	12.0	11.3	10.6
120	18.8	16.7	15.0	13.6	12.5	11.5	10.7	10.0	9.4	8.8
140	16.1	14.3	12.9	11.7	10.7	9.9	9.2	8.6	8.0	7.6
160	14.1	12.5	11.3	10.2	9.4	8.7	8.0	7.5	7.0	6.6
180	12.5	11.1	10.0	9.1	8.3	7.7	7.1	6.7	6.3	5.9
200	11.3	10.0	9.0	8.2	7.5	6.9	6.4	6.0	5.6	5.3
220	10.2	9.1	8.2	7.4	6.8	6.3	5.8	5.5	5.1	4.8
240	9.4	8.3	7.5	6.8	6.3	5.8	5.4	5.0	4.7	4.4
260	8.7	7.7	6.9	6.3	5.8	5.3	4.9	4.6	4.3	4.1
280	8.0	7.1	6.4	5.8	5.4	4.9	4.6	4.3	4.0	3.8
300	7.5	6.7	6.0	5.5	5.0	4.6	4.3	4.0	3.8	3.5
320	7.0	6.3	5.6	5.1	4.7	4.3	4.0	3.8	3.5	3.3
340	6.6	5.9	5.3	4.8	4.4	4.1	3.8	3.5	3.3	3.1
360	6.3	5.6	5.0	4.5	4.2	3.8	3.6	3.3	3.1	2.9
380	5.9	5.3	4.7	4.3	3.9	3.6	3.4	3.2	3.0	2.8
400	5.6	5.0	4:5	4.1	3.8	3.5	3.2	3.0	2.8	2.6
420	5.4	4.8	4.3	3.9	3.6	3.3	3.1	2.9	2.7	2.5
440	5.1	4.5	4.1	3.7	3.4	3.1	2.9	2.7	2.6	2.4
460	4.9	4.3	3.9	3.6	3.3	3.0	2.8	2.6	2.4	2.3
480	4.7	4.2	3.8	3.4	3.1	2.9	2.7	2.5	2.3	2.2
500	4.5	4.0	3.6	3.3	3.0	2.8	2.6	2.4	2.2	2.1
520	4.3	3.8	3.5	3.1	2.9	2.7	2.5	2.3	2.2	2.0
540	4.2	3.7	3.3	3.0	2.8	2.6	2.4	2.2	2.1	2.0
560	4.0	3.6	3.2	2.9	2.7	2.5	2.3	2.1	2.0	1.9
580	3.9	3.4	3.1	2.8	2.6	2.4	2.2	2.1	1.9	1.8
600	3.8	3.3	3.0	2.7	2.5	2.3	2.1	2.0	1.9	1.8

Note: Formula used for calculation:

$$L = \frac{2000(9)}{R\ W} = \frac{18000}{R\ W}$$

Where:
L = Lineal feet covered by one ton of material
R = Rate of spread in lbs per sq yd
W = Width of spread in feet

TABLE I-19

CUBIC YARDS OF MATERIAL REQUIRED FOR VARIOUS WIDTHS AND DEPTHS PER 100 LINEAR FEET AND PER MILE

	Width, Feet	Depth—Inches											
		1	2	3	4	5	6	7	8	9	10	11	12
PER 100 LINEAR FEET	1	0.31	0.62	0.93	1.23	1.54	1.85	2.16	2.47	2.78	3.09	3.40	3.70
	2	0.62	1.23	1.85	2.47	3.09	3.70	4.32	4.94	5.56	6.17	6.79	7.41
	3	0.93	1.85	2.78	3.70	4.63	5.56	6.48	7.41	8.33	9.26	10.2	11.1
	4	1.23	2.47	3.70	4.94	6.17	7.41	8.64	9.88	11.1	12.3	13.6	14.8
	5	1.54	3.09	4.63	6.17	7.72	9.26	10.8	12.3	13.9	15.4	17.0	18.5
	6	1.85	3.70	5.56	7.41	9.26	11.1	13.0	14.8	16.7	18.5	20.4	22.2
	7	2.16	4.32	6.48	8.64	10.8	13.0	15.1	17.3	19.4	21.6	23.8	25.9
	8	2.47	4.94	7.41	9.88	12.3	14.8	17.3	19.8	22.2	24.7	27.2	29.6
	9	2.78	5.56	8.33	11.1	13.9	16.7	19.4	22.2	25.0	27.8	30.6	33.3
	10	3.09	6.17	9.26	12.3	15.4	18.5	21.6	24.7	27.8	30.9	34.0	37.0
	20	6.17	12.3	18.5	24.7	30.9	37.0	43.2	49.4	55.6	61.7	67.9	74.1
	30	9.26	18.5	27.8	37.0	46.3	55.6	64.8	74.1	83.3	92.6	102	111
	40	12.3	24.7	37.0	49.4	61.7	74.1	86.4	98.8	111	123	136	148
	50	15.4	30.9	46.3	61.7	77.2	92.6	108	123	139	154	170	185
	60	18.5	37.0	55.6	74.1	92.6	111	130	148	167	185	204	222
	70	21.6	43.2	64.8	86.4	108	130	151	173	194	216	238	259
	80	24.7	49.4	74.1	98.8	123	148	173	198	222	247	272	296
	90	27.8	55.6	83.3	111	139	167	194	222	250	278	306	333
	100	30.9	61.7	92.6	123	154	185	216	247	278	309	340	370
PER MILE	1	16.3	32.6	48.9	65.2	81.5	97.8	114	130	147	163	179	196
	2	32.6	65.2	97.8	130	163	196	228	261	293	326	359	391
	3	48.9	97.8	147	196	244	293	342	391	440	489	538	587
	4	65.2	130	196	261	326	391	456	521	587	652	717	782
	5	81.5	163	244	326	407	489	570	652	733	815	896	978
	6	97.8	196	293	391	489	587	684	782	880	978	1076	1173
	7	114	228	342	456	570	684	799	913	1027	1141	1255	1369
	8	130	261	391	521	652	782	913	1043	1173	1304	1434	1564
	9	147	293	440	587	733	880	1027	1173	1320	1467	1613	1760
	10	163	326	489	652	815	978	1141	1304	1467	1630	1793	1956
	20	326	652	978	1304	1630	1956	2281	2607	2933	3259	3585	3911
	30	489	978	1467	1956	2444	2933	3422	3911	4440	4889	5378	5867
	40	652	1304	1956	2607	3259	3911	4563	5215	5867	6519	7170	7822
	50	815	1630	2444	3259	4074	4889	5704	6519	7333	8148	8963	9778
	60	978	1956	2933	3911	4889	5867	6844	7822	8800	9778	10756	11733
	70	1141	2281	3422	4563	5704	6844	7985	9126	10267	11407	12548	13689
	80	1304	2607	3911	5215	6519	7822	9126	10430	11733	13037	14341	15644
	90	1467	2933	4400	5867	7333	8800	10267	11733	13200	14667	16133	17600
	100	1630	3259	4889	6519	8148	9778	11407	13037	14667	16296	17926	19556

Note: Formulas used for calculation:

Per 100 Lin Ft: $q = \left(\frac{D}{36}\right)\left(\frac{W}{3}\right)\left(\frac{100}{3}\right) = 0.3086DW$

Per Mile: $q = \left(\frac{D}{36}\right)\left(\frac{W}{3}\right)\left(\frac{5280}{3}\right) = 16.2963DW$

Where: q = Quantity of material in cubic yards
D = Depth in inches
W = Width in feet

TABLE I-20

SPECIFIC GRAVITY AND DENSITY OF MISCELLANEOUS SOLIDS AND LIQUIDS

Important Note

The specific gravity and density of most materials included in this table will vary through a range of values. Accordingly, ranges are indicated. Such ranges, however, are not necessarily all-inclusive as values will occasionally be encountered which will fall outside the indicated range.

Where solids are concerned, the specific gravity and density shown are for the material in solid form. To determine the density or unit weight of the material in crushed or granular form, it is also necessary to know the void content which, in turn, depends upon the gradation and degree of compaction of such materials. Knowing the void content and specific gravity, the bulk density or unit weight of the material in crushed or granular form may be obtained from Table 1-13.

It is preferable to determine both the specific gravity and the void content by appropriate test. The data provided below should therefore be used only for estimating purposes.

Specific Gravities and Densities of Miscellaneous Solid and Liquid Materials

Material	*Sp Gr*	*Weight lbs/cu ft*
Alcohol, ethyl, pure	0.79	49.2
Aluminum	2.55–2.80	159–175
Aluminum oxide	3.95–4.00	
Asbestos	2.1–2.8	131–175
Asbestos paper		13.0–22.0
Asbestos sheet		53–56
Asphalt cement	0.99–1.04	61.8–64.9
Asphalt, liquid	0.92–1.01	57.4–63.0
Asphalt, natural	1.00–1.42	62.4–88.6
Basalt	2.7–3.2	168–200
Benzene	0.73–0.75	45.6–46.8
Brass	8.4–8.7	524–543
Brick, building	1.4–1.9	87–119
Brick, paving	1.8–2.3	112–114
Bronze	7.4–8.9	462–556
Calcium carbonate, pure	2.71	
Calcium chloride (anhydrous)	2.15	
Carbon, amorphous (carbon black)	1.8–2.1	
Carbon disulphide	1.26	78.7
Carbon tetrachloride	1.59	99.5
Cement, portland	3.1–3.2	
Cement, portland, loose		94
Cement mortar, portland		130–140
Cinders		40–45
Clay	2.5–2.7	
Coal	1.2–1.5	75–93
Concrete, asphalt	2.16–2.48	135–155
Concrete, portland cement	2.2–2.4	137–150
Copper	8.8–8.95	549–559
Cork	0.22–0.26	13–16
Creosote	1.03–1.08	64.3–67.4
Dolomite	2.8–2.9	174–181
Earth, loamy, dry		100–118
Feldspar	2.5–2.7	156–168
Felt		16–21
Gasoline	0.70–0.75	43.7–46.8
Glass	2.4–2.8	150–175
Granite	2.6–2.9	162–181
Graphite	2.3–2.7	143–168
Gravel	2.50–2.70	
Gypsum, calcined	1.81	
Ice	0.88–0.92	55–58
Iron, cast, pig	7.2	450
Iron, wrought	7.6–7.9	474–493
Kerosene	0.78–0.82	48.7–51.2
Lead	11.34	707.9
Leather	0.86–1.02	53–64
Limestone	2.1–2.8	131–175
Lime, quick (calcium oxide)	2.62	
Lime, hydrated or slaked (calcium hydroxide)	2.20	
Lubricating oil	0.86–0.94	53.7–58.7
Mercury at 20°C	13.546	845.65
Mica, muscovite	2.7–3.1	168–194
Naphtha, petroleum ether	0.63–0.66	39.3–41.2
Paraffin wax	0.85–0.95	53.0–59.3
Peat		20–40
Petroleum	0.91–1.04	56.8–64.9
Pitch	1.07–1.15	67–72
Quartz, flint	2.5–2.8	156–175
Rubber	0.92–0.96	57–60
Salt (sodium chloride)	2.16	134.8
Sand	2.5–2.7	
Sandstone	2.0–2.7	125–168
Slate	2.6–2.9	162–181
Slag, granulated	1.4–1.6	
Slag, blast furnace	2.0–2.5	
Steel	7.8–7.9	487–493
Tar	0.95–1.25	59–78
Timber (air dry)		
Fir, Douglas	0.48–0.55	30–34
Oak, Chestnut	0.74	46.2
Pine, Southern	0.61–0.67	38–42
Redwood, California	0.42	26.1
Trap Rock	2.7–3.2	168–200
Water, distilled, 39.2°F (+4°C)	1.00	62.43
Water, sea	1.02–1.04	63.6–64.9

TABLE I-21

CONVERSION OF LINEAR MEASUREMENTS
FEET TO MILES AND MILES TO FEET

FEET TO MILES	Feet	1	2	3	4	5	6	7	8	9
	Miles	0.00019	0.00038	0.00057	0.00076	0.00095	0.00114	0.00133	0.00152	0.00171
	Feet	10	20	30	40	50	60	70	80	90
	Miles	0.00189	0.00379	0.00568	0.00758	0.00947	0.01136	0.01326	0.01515	0.01705
	Feet	100	200	300	400	500	600	700	800	900
	Miles	0.01894	0.03788	0.05682	0.07576	0.09470	0.11364	0.13258	0.15152	0.17046
	Feet	1000	2000	3000	4000	5000	6000	7000	8000	9000
	Miles	0.18939	0.37879	0.56818	0.75758	0.94697	1.13636	1.32576	1.51515	1.70455
	Feet	10000	20000	30000	40000	50000	60000	70000	80000	90000
	Miles	1.8939	3.7879	5.6818	7.5758	9.4697	11.3636	13.2576	15.1515	17.0455

MILES TO FEET	Miles	0.1	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
	Feet	528	5280	5808	6336	6864	7392	7920	8448	8976	9504	10032
	Miles	0.2	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
	Feet	1056	10560	11088	11616	12144	12672	13200	13728	14256	14784	15312
	Miles	0.3	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9
	Feet	1584	15840	16368	16896	17424	17952	18480	19008	19536	20064	20592
	Miles	0.4	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9
	Feet	2112	21120	21648	22176	22704	23232	23760	24288	24816	25344	25872
	Miles	0.5	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9
	Feet	2640	26400	26928	27456	27984	28512	29040	29568	30096	30624	31152
	Miles	0.6	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	.9
	Feet	3168	31680	32208	32736	33264	33792	34320	34848	35376	35904	36432
	Miles	0.7	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9
	Feet	3696	36960	37488	38016	38544	39072	39600	40128	40656	41184	41712
	Miles	0.8	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9
	Feet	4224	42240	42768	43296	43824	44352	44880	45408	45936	46464	46992
	Miles	0.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9
	Feet	4752	47520	48048	48576	49104	49632	50160	50688	51216	51744	52272

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TABLE I–22

CONVERSION FACTORS—LENGTH MEASUREMENTS

Units	Inches	Feet	Yards	Rods	Miles	Meters
1 Inch	1	0.08333	0.027778	0.005051	0.0000157828	0.0254
1 Foot	12	1	0.3333	0.060606	0.00018939	0.304801
1 Yard	36	3	1	0.181818	0.000568182	0.914402
1 Rod (Surveyor's Measure)	198	16.5	5.5	1	0.003125	5.029216
1 Mile (U.S. Statute)	63360	5280	1760	320	1	1609.347
1 Meter	39.37	3.280833	1.093611	0.198838	0.00062137	1
1 Link	7.92	0.66	0.22	0.04	0.000125	0.201168
1 Chain (Surveyor's)	792	66	22	4	0.0125	20.117
1 Station	1200	100	33.33	6.060606	0.0189394	30.4801
1 Furlong	7920	660	220	40	0.125	201.168
1 Mile (Int. Nautical)	729132	6076.103	2025.366	368.248	1.15078	1852
1 Millimeter	0.03937	0.003281	0.001094	0.000199	—	0.001
1 Centimeter	0.3937	0.032808	0.010936	0.001988	—	0.01
1 Kilometer	—	3280.833	1093.611	198.836	0.621370	1000

TABLE I–23

CONVERSION FACTORS—AREA MEASUREMENTS

Units	Square Inches	Square Feet	Square Yards	Square Rods	Acres	Square Miles	Square Meters
1 Square Inch	1	0.006944	0.0007716	—	—	—	0.00064516
1 Square Foot	144	1	0.11111	0.0036731	—	—	0.09290341
1 Square Yard	1296	9	1	0.033058	0.0002066	—	0.8361307
1 Square Rod	39204	272.25	30.25	1	0.00625	—	25.29295
1 Acre	—	43560	4840	160	1	0.0015625	4046.873
1 Square Mile	—	—	3097600	102400	640	1	2589998
1 Square Meter	1550	10.76387	1.195985	0.0395367	0.0002471	—	1
1 Square Link	62.7264	0.4356	0.0484	0.0016	0.00001	—	0.040468
1 Square Chain	627264	4356	484	16	0.1	—	404.689
1 Square	14400	100	11.1111	0.367309	0.0022956	—	9.29034
1 Section	—	—	3097600	102400	640	1	2589998
1 Square Centimeter	0.1549997	0.0010764	0.0001196	—	—	—	0.0001
1 Hectare	—	107638.7	11959.85	395.367	2.471044	0.003861	10000
1 Square Kilometer	—	—	1195985	39536.7	247.1044	0.3861006	1000000

TABLE I-24

CONVERSION FACTORS—VOLUME MEASUREMENTS

Units	Cubic Inches	Cubic Feet	Cubic Yards	Pints (Liquid)	Quarts (Liquid)	Gallons (U.S.)	Liters (1000 cc)
1 Cubic Inch	1	0.000579	0.0000214	0.034632	0.017316	0.004329	0.016387
1 Cubic Foot	1728	1	0.037037	59.844	29.922	7.4805	28.31625
1 Cubic Yard	46656	27	1	1615.8	807.9	201.975	764.54
1 Pint (Liquid)	28.875	0.016710	0.000619	1	0.5	0.125	0.473168
1 Quart (Liquid)	57.75	0.033420	0.001238	2	1	0.25	0.946333
1 Gallon (U.S.)	231	0.1336805	0.004951	8	4	1	3.78533
1 Liter (1000 cc)	61.025	0.035316	0.001308	2.11336	1.056682	0.264178	1
1 Gill	7.21876	0.004177	0.000155	0.25	0.125	0.03125	0.118292
1 Pint (Dry)	33.6003	0.019445	0.000720	1.163647	0.581823	0.145456	0.550599
1 Quart (Dry)	67.200625	0.038889	0.001440	2.32730	1.163646	0.290912	1.10120
1 Quart (Imperial)	69.35503	0.040135	0.001486	2.4019	1.200953	0.300238	1.13650
1 Gallon (Imperial)	277.4201	0.16054	0.0059457	9.60762	4.80381	1.20095	4.54609
1 Peck	537.605	0.311114	0.011523	18.61835	9.309177	2.327294	8.809586
1 Bushel (US)	2150.42	1.2444	0.046089	74.47341	37.23670	9.3092	35.238329
1 Board Foot	144	0.08333	0.003086	4.987012	2.493506	0.623376	2.3597
1 Cord	221184	128	4.74074	7660.051	3830.025	957.506	3624.48
1 Petroleum Barrel	9701.975	5.614569	0.207947	336	168	42	158.9839
1 Barrel (U.S. Liquid)	7276.370	4.21086	0.15596	252	126	31.5	119.237895
1 Cubic Meter	61023.38	35.314445	1.307943	2113.4	1056.7	264.178	999.973
1 Cubic Centimeter	0.061024	0.0000353	—	0.002113	0.001057	0.0002642	0.000999

TABLE I-25

CONVERSION FACTORS—WEIGHT MEASUREMENTS

Units	Ounces	Pounds	Tons (Short)	Tons (Long)	Kilograms	Tons (Metric)
1 Ounce	1	0.0625	—	—	0.0028349	—
1 Pound	16	1	0.0005	0.0004464	0.4535924	0.00045359
1 Ton (Short)	32000	2000	1	0.892857	907.18486	0.907185
1 Ton (Long)	35840	2240	1.12	1	1016.047	1.016047
1 Kilogram	35.27396	2.204622	0.0011023	0.0009842	1	0.001
1 Ton (Metric)	35273.96	2204.62	1.10231	0.98421	1000	1
1 Hundredweight (Short)	1600	100	0.05	0.044643	45.3592	0.045359
1 Hundredweight (Long)	1792	112	0.056	0.05	50.8023	0.050802
1 Grain	0.0022857	—	—	—	—	—
1 Gram	0.0352739	0.002204	—	—	0.001	—
1 Milligram	—	—	—	—	0.000001	—

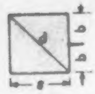
TABLE I-26

CONVERSION FACTORS
MISCELLANEOUS

Multiply	By	To Obtain
Pounds per foot	1.48816	Kilograms per meter
Pounds per square foot	4.88241	Kilograms per square meter
Pounds per square inch	0.07031	Kilograms per square cm.
Pounds per square inch	0.0007031	Kilograms per square mm.
Pounds per cubic foot	16.0184	Kilograms per cubic meter
Radians	57.29578	Degrees, angular
Horsepower	550	Ft-Lbs per second
Horsepower	2544	B.T.U.'s per hour
Horsepower	745.5	Watts
B.T.U.	251.98	Calories, gram
B.T.U.	777.98	Ft-Lbs
Feet per second	0.68182	Miles per hour
Miles per hour	88	Feet per minute
Miles per hour	1.46667	Feet per second
Pounds	444822	Dynes
Kilograms	980665	Dynes
Atmosphere	1.0333	Kilograms per square cm.
Atmosphere	14.697	Pounds per square inch
Atmosphere	29.921	Inches of mercury (0°C. at sea level)
Atmosphere	0.76	Meters of mercury (0°C. at sea level)
Atmosphere	33.9	Feet of water (4°C. at sea level)
Pounds of water per minute	0.016021	Cubic feet per minute
Cubic feet per minute	0.12468	Gallons per second
Fathoms	6	Feet
Degrees per foot	0.00057261	Radians per centimeter
Centimeters of mercury (at 20°C.)	5.34	Inches of water (at 20°C.)

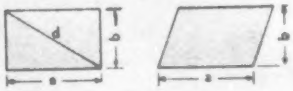
TABLE I-27

AREAS OF PLANE FIGURES



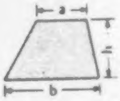
Square

Diagonal = $d = s\sqrt{2}$.
Area = $s^2 = 4b^2 = 0.5d^2$.
Example. $s = 6$; $b = 3$. Area = $(6)^2 = 36$ Ans.
$d = 6 \times 1.414 = 8.484$ Ans.



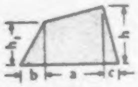
Rectangle and Parallelogram

Area = ab or $b\sqrt{d^2 - b^2}$
Example. $a = 6$; $b = 3$.
Area = $3 \times 6 = 18$ Ans.



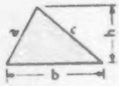
Trapezoid

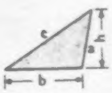
Area = $\frac{1}{2}h(a + b)$
Example. $a = 2$; $b = 4$; $h = 3$.
Area = $\frac{1}{2} \times 3(2 + 4) = 9$. Ans.



Trapezium

Area = $\frac{1}{2}[a(h + h^1) + bh^1 + ch]$
Example. $a = 4$; $b = 2$; $c = 2$; $h = 3$; $h^1 = 2$.
Area = $\frac{1}{2}[4(3 + 2) + (2 \times 2) + (2 \times 3)] = 15$. Ans.





Triangles

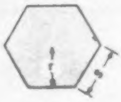
Both formulas apply to both figures
Area = $\frac{1}{2}bh$.
Example. $h = 3$; $b = 5$.
Area = $\frac{1}{2}(3 \times 5) = 7\frac{1}{2}$. Ans.

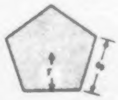
Area = $\sqrt{S(S - a)(S - b)(S - c)}$ when $S = \frac{a + b + c}{2}$

Example. $a = 2$; $b = 3$; $c = 4$.

$$S = \frac{2 + 3 + 4}{2} = 4.5$$

Area = $\sqrt{4.5(4.5 - 2)(4.5 - 3)(4.5 - 4)} = 2.9$. Ans.



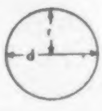


Regular Polygons

Area	5 sides	$= 1.720477\ S^2$	$= 3.63271\ r^2$
	6 "	$= 2.598150\ S^2$	$= 3.46410\ r^2$
	7 "	$= 3.633875\ S^2$	$= 3.37101\ r^2$
	8 "	$= 4.828427\ S^2$	$= 3.31368\ r^2$
	9 "	$= 6.181875\ S^2$	$= 3.27573\ r^2$
	10 "	$= 7.694250\ S^2$	$= 3.24920\ r^2$
	11 "	$= 9.365675\ S^2$	$= 3.22993\ r^2$
	12 "	$= 11.196300\ S^2$	$= 3.21539\ r^2$

n = number of sides; r = short radius;
S = length of side; R = long radius.

$$\text{Area} = \frac{n}{4} S^2 \cot. \frac{180^\circ}{n} = \frac{n}{2} R^2 \sin. \frac{360^\circ}{n} = nr^2 \tan \frac{180^\circ}{n}$$



Circle

$\pi = 3.1416$; A = area; d = diameter; p = circumference or periphery; r = radius.

$p = \pi d = 3.1416d$. $\quad p = 2\sqrt{\pi A} = 3.54\sqrt{A}$

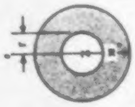
$p = 2\pi r = 6.2832r$. $\quad p = \frac{2A}{r} = \frac{4A}{d}$

$d = \frac{p}{\pi} = \frac{p}{3.1416}$ $\quad d = 2\sqrt{\frac{A}{\pi}} = 1.128\sqrt{A}$

$r = \frac{p}{2\pi} = \frac{p}{6.2832}$ $\quad r = \sqrt{\frac{A}{\pi}} = 0.564\sqrt{A}$

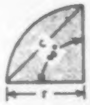
$A = \frac{\pi d^2}{4} = 0.7854d^2$ $\quad A = \frac{p^2}{4\pi} = \frac{p^2}{12.57}$

$A = \pi r^2 = 3.1416r^2$ $\quad A = \frac{pr}{2} = \frac{pd}{4}$



Circular Ring

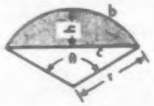
Area = $\pi(R^2 - r^2) = 3.1416(R^2 - r^2)$
Area = $0.7854(D^2 - d^2) = 0.7854(D - d)(D + d)$
Area = difference in areas between the inner and outer circles.
Example. $R = 4$; $r = 2$.
Area = $3.1416(4^2 - 2^2) = 37.6992$. Ans.



Quadrant

Area = $\frac{\pi r^2}{4} = 0.7854r^2 = 0.3927c^2$.

Example. $r = 3$. c = chord.
Area = $.7854 \times 3^2 = 7.0686$. Ans.



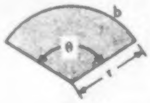
Segment

b = length of arc. θ = angle in degrees
c = chord = $\sqrt{4(2hr - h^2)}$
Area = $\frac{1}{2}[br - c(r - h)]$
$= \pi r^2 \frac{\theta}{360} - \frac{c(r - h)}{2}$

When θ is greater than 180° then $\frac{c}{2} \times$ difference between r and h is added to the fraction $\frac{\pi r^2\theta}{360}$

Example. $r = 3$; $\theta = 120^\circ$; $h = 1.5$

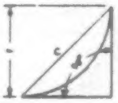
Area = $3.1416 \times 3^2 \times \frac{120}{360} - \frac{5.196(3 - 1.5)}{2}$
$= 5.5278$. Ans.



Sector

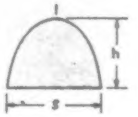
Area = $\frac{br}{2} = \pi r^2 \frac{\theta}{360^\circ}$
θ = angle in degrees; b = length of arc.
Example. $r = 3$; $\theta = 120^\circ$

Area = $3.1416 \times 3^2 \times \frac{120}{360} = 9.4248$. Ans.



Spandrel

Area = $0.2146r^2 = 0.1073c^2$
Example. $r = 3$
Area = $0.2146 \times 3^2 = 1.9314$. Ans



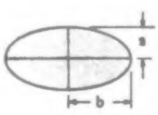
Parabola

l = length of curved line = periphery − s

$l = \frac{s^2}{8h}[\sqrt{c(1+c)} + 2.0326 \times \log(\sqrt{c} + \sqrt{1+c})]$

in which $c = \left(\frac{4h}{s}\right)^2$

Area = $\frac{2}{3}sh$
Example. $s = 3$; $h = 4$
Area = $\frac{2}{3} \times 3 \times 4 = 8$. Ans.



Ellipse

Area = $\pi ab = 3.1416ab$

Circum. = $2\pi\sqrt{\frac{a^2 + b^2}{2}}$ (close approximation)

Example. $a = 3$; $b = 4$.
Area = 3.1416 x 3 x 4 = 37.6992. Ans.

Circum. = $2 \times 3.1416\sqrt{\frac{(3)^2 + (4)^2}{2}}$
$= 6.2832 \times 3.5355 = 22.21$ Ans.

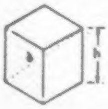
TABLE I-28

VOLUME AND SURFACE AREA OF SOLIDS

Symbols

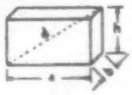
V = Volume
S = Lateral Surface Area
T = Total Surface Area
B = Area of Base
P = Perimeter Perpendicular to Sides
P_b = Perimeter of Base
A = Area of Section Perpendicular to Sides
l = Lateral Length
h = Perpendicular Height
d = Diagonal Length

Cube



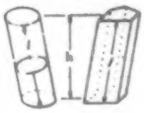
$V = h^3$
$T = 6h^2$
$S = 4h^2$
$d = h\sqrt{3}$

Rectangular Prism



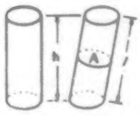
$V = abh$
$T = 2(ab + ah + bh)$
$S = 2(ah + bh)$
$d = \sqrt{a^2 + b^2 + h^2}$

Prism or Cylinder, Right or Oblique, Parallel Ends



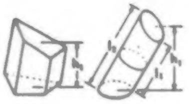
$V = Al$
$S = Pl$
$T = Pl + 2B$
(Note $A = B$, $P = P_b$ and $l = h$ for right cylinders and prisms

Cylinder, Right or Oblique, Circular or Otherwise, Parallel Ends



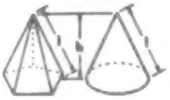
$V = Bh$ (Right Cylinder)
$V = Al$ (Oblique Cylinder)
$S = P_bh$ (Right Cylinder)
$S = Pl$ (Oblique Cylinder)
$T = P_bh + 2B$ (Right Cylinder)
$T = Pl + 2B$ (Oblique Cylinder)

Frustrum of Prism or Cylinder



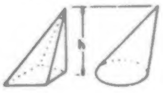
$V = Bh_1$ (where h_1 is perpendicular height from base to c.g. of top)
or, for cylinder
$V = \frac{A}{2}(l_1 + l_2)$

Pyramid or Cone, Right and Regular



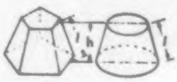
$V = \frac{Bh}{3}$
$S = \frac{P_bl}{2}$
$T = \frac{P_bl}{2} + B$

Pyramid or Cone, Right or Oblique, Regular or Irregular



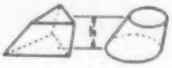
$V = \frac{Bh}{3}$

Frustrum of Pyramid or Cone, Right and Regular, Parallel Ends



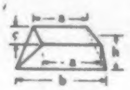
$V = \frac{h}{3}(B + B_1 + \sqrt{BB_1})$
$S = \frac{l}{2}(P_b + P_T)$
$T = \frac{l}{2}(P_b + P_T) + B + B_1$
where: B_1 = Area of Top
P_T = Perimeter of Top

Frustrum of Any Pyramid or Cone, Parallel Ends



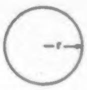
$V = \frac{h}{3}(B + B_1 + \sqrt{BB_1})$
where: B_1 = Area of Top

Wedge, Regular



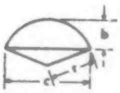
$V = \frac{ch}{6}(2a + b)$

Sphere



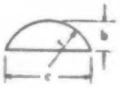
$V = \frac{4\pi r^3}{3}$
$S = 4\pi r^2$

Spherical Sector



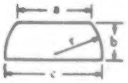
$S = \frac{1}{2}\pi r(4b + c)$
$V = \frac{2}{3}\pi r^2b$

Spherical Segment



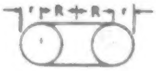
$S = 2\pi rb = \frac{1}{4}\pi(4b^2 + c^2)$
$V = \frac{1}{3}\pi b^2(3r - b)$
$= \frac{1}{24}\pi b(3c^2 + 4b^2)$

Spherical Zone



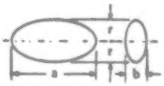
$S = 2\pi rb$
$V = \frac{1}{24}\pi b(3a^2 + 3c^2 + 4b^2)$

Circular Ring



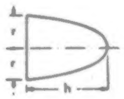
$S = 4\pi^2Rr$
$V = 2\pi^2Rr^2$

Ellipsoid



$V = \frac{1}{3}\pi rab$

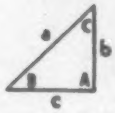
Paraboloid



$V = \frac{1}{2}\pi r^2h$

TABLE I-29

TRIGONOMETRIC RELATIONS AND SOLUTIONS OF RIGHT ANGLE TRIANGLES



As shown in the illustration, the sides of the right angled triangle are designated *a*, *b* and *c*. The angles opposite each of these sides are designated *A*, *B* and *C* respectively.

Angle *A*, opposite the hypotenuse *a* is the right angle and is therefore always one of the known quantities.

Sides and Angles Known	Formulas for Sides and Angles to be Found		
Sides a and b	$c = \sqrt{a^2 - b^2}$	$\sin B = \frac{b}{a}$	$C = 90° - B$
Sides a and c	$b = \sqrt{a^2 - c^2}$	$\sin C = \frac{c}{a}$	$B = 90° - C$
Sides b and c	$a = \sqrt{b^2 + c^2}$	$\tan B = \frac{b}{c}$	$C = 90° - B$
Side a; angle B	$b = a \times \sin B$	$c = a \times \cos B$	$C = 90° - B$
Side a; angle C	$b = a \times \cos C$	$c = a \times \sin C$	$B = 90° - C$
Side b; angle B	$a = \frac{b}{\sin B}$	$c = b \times \cot B$	$C = 90° - B$
Side b; angle C	$a = \frac{b}{\cos C}$	$c = b \times \tan C$	$B = 90° - C$
Side c; angle B	$a = \frac{c}{\cos B}$	$b = c \times \tan B$	$C = 90° - B$
Side c; angle C	$a = \frac{c}{\sin C}$	$b = c \times \cot C$	$B = 90° - C$

TABLE I-30

ASPHALT BLOCK WEIGHT AND QUANTITY RELATIONSHIPS

Size	Pounds per Block	Pounds per Sq Ft	Pounds per Sq Yd	Net Tons per Thousand Blocks	Number of Blocks		Per M Blocks	
					per Sq Ft	per Sq Yd	Sq Ft	Sq Yd
5″ x 12″ x 2″	10.5	25.2	227	5.25	2.4	21.6	417	46
5″ x 12″ x 2½″	12.9	31.0	279	6.45	2.4	21.6	417	46
5″ x 12″ x 3″	16.1	38.6	347	8.05	2.4	21.6	417	46
4″ x 8″ x 1¼″	3.4	15.3	138	1.70	4.50	40.5	222	25
4″ x 8″ x 1½″	4.1	18.5	167	2.05	4.50	40.5	222	25
4″ x 8″ x 2″	5.7	25.6	230	2.85	4.50	40.5	222	25
8″ x 16″ x 1¼″	14.3	16.1	145	7.15	1.13	10.2	889	99
8″ x 16″ x 1½″	16.8	18.9	170	8.40	1.13	10.2	889	99
8″ x 16″ x 2″	22.1	24.9	224	11.05	1.13	10.2	889	99
8″ x 16″ x 2½″	27.75	31.2	281	13.875	1.13	10.2	889	99
8″ x 16″ x 3″	32.25	36.3	327	16.125	1.13	10.2	889	99
Hexagonal Tiles	10.7	25.0	225	5.35	2.33	21.0	432	
Square Tiles	11.8	26.4	238	5.90	2.44	20.2	441	

TABLE I-31

REQUIREMENTS FOR U. S. STANDARD TESTING SIEVES AND APPROXIMATE EQUIVALENTS OF SQUARE AND ROUND OPENINGS

U. S. STANDARD SIEVES

STANDARD REQUIREMENTS FOR CERTAIN SIZES

Size of Sieve Designation	Sieve Opening		Permissible Variations in Average Opening, Percent	Permissible Variations in Maximum Opening, Percent	Wire Diameter	
	mm.	in. (Approximate Equivalents)			mm.	in. (Approximate Equivalents)
3 in.	76.2	3.00	±2	+3	4.8 to 8.1	0.190 to 0.320
2½ in.	63.5	2.50	±2	+3	4.4 to 7.1	0.175 to 0.280
2 in.	50.8	2.00	±2	+3	4.1 to 6.2	0.160 to 0.245
1½ in.	38.1	1.50	±2	+3	3.7 to 5.3	0.145 to 0.210
1¼ in.	31.7	1.25	±2	+3	3.5 to 4.8	0.140 to 0.190
1 in.	25.4	1.00	±3	+5	3.43 to 4.50	0.135 to 0.177
¾ in.	19.1	0.750	±3	+5	3.10 to 3.91	0.122 to 1.054
½ in.	12.7	0.500	±3	+5	2.39 to 3.10	0.094 to 0.122
⅜ in.	9.52	0.375	±3	+5	2.11 to 2.59	0.083 to 0.102
¼ in.	6.35	0.250	±3	+5	1.60 to 2.11	0.063 to 0.083
No. 4	4.76	0.187	±3	+10	1.14 to 1.68	0.045 to 0.066
No. 8	2.38	0.0937	±3	+10	0.74 to 1.10	0.0291 to 0.0433
No. 10	2.00	0.0787	±3	+10	0.68 to 1.00	0.0268 to 0.0394
No. 16	1.19	0.0469	±3	+10	0.50 to 0.70	0.0197 to 0.0276
No. 20	0.84	0.0331	±5	+15	0.38 to 0.55	0.0150 to 0.0217
No. 30	0.59	0.0232	±5	+15	0.29 to 0.42	0.0114 to 0.0165
No. 40	0.42	0.0165	±5	+25	0.23 to 0.33	0.0091 to 0.0130
No. 50	0.297	0.0117	±5	+25	0.170 to 0.253	0.0067 to 0.0100
No. 80	0.177	0.0070	±6	+40	0.114 to 0.154	0.0045 to 0.0061
No. 100	0.149	0.0059	±6	+40	0.096 to 0.125	0.0038 to 0.0049
No. 200	0.074	0.0029	±7	+60	0.045 to 0.061	0.0018 to 0.0024

APPROXIMATE EQUIVALENTS OF SQUARE AND ROUND OPENINGS

Inches		Inches	
Square	Round	Square	Round
3	3½	⅞	1
2½	3	¾	⅞
2⅛	2½	⅝	¾
2	2⅜	½	⅝
1¾	2	⅜	½
1½	1¾	5/16	⅜
1¼	1½	¼	5/16
1	1¼	3/16 (No. 4)	¼

TABLE I-32

APPROXIMATE PROCEDURE FOR TRANSFORMING "PASSING-RETAINED" SPECIFICATION TO AN EQUIVALENT "TOTAL PERCENT PASSING" SPECIFICATION

Assumed "Passing-Retained" Specification					Step 1		Step 2		Step 3		Step 4	
Passing	Retained	Percent Total Material		Sieve Size	Cumulative Percent Passing, Fine to Coarse Sizes		Cumulative Percent Retained, Coarse to Fine Sizes		Cumulative Percent Passing, Coarse to Fine Sizes		Equivalent Specification on "Total Percent Passing" Basis*	
					Min.	Max.	Min.	Max.	Min.	Max.		
Col. No. 1	Col. No. 2	Col. No. 3	4	Col. No. 5	Col. No. 6	Col. No. 7	Col. No. 8	Col. No. 9	Col. No. 10	Col. No. 11	Col. No. 12	Col. No. 13
				1½ in.	63	100+						
1½ in.	1 in.	0	18	1 in.	63	100+	0	18	100	82	82	100
1 in.	¾ in.	4	11	¾ in.	59	100+	4	29	96	71	71	96
¾ in.	½ in.	5	12	½ in.	54	93	9	41	91	59	59	91
½ in.	⅜ in.	3	9	⅜ in.	51	84	12	50	88	50	51	84
⅜ in.	#4	9	13	#4	42	71	21	63	79	37	42	71
#4	#8	10	14	#8	32	57	31	77	69	23	32	57
#8	#16	8	12	#16	24	45	39	89	61	11	24	45
#16	#30	7	11	#30	17	34	46	100+	54	0	17	34
#30	#50	6	10	#50	11	24	52	100+	48	0	11	24
#50	#100	5	9	#100	6	15	57	100+	43	0	6	15
#100	#200	4	8	#200	2	7	61	100+	39	0	2	7
#200		2	7									

Notes: COLUMN 5 is the same as *Column* 2 repeated for convenience and clarity

COLUMN 6 is derived by *adding* the values in *Column* 3 from *Fine to Coarse*

COLUMN 7 is derived by *adding* the values in *Column* 4 from *Fine to Cocrse*

COLUMN 8 is derived by *adding* the values in *Column* 3 from *Coarse to Fine*

COLUMN 9 is derived by *adding* the values in *Column* 4 from *Coarse to Fine*

COLUMN 10 is derived by *subtracting* the values in *Column* 8 from 100 (i.e. *Column* 10 = 100 − *Column* 8)

COLUMN 11 is derived by *subtracting* the values in *Column* 9 from 100 (i.e. *Column* 11 = 100 − *Column* 9)

The values for COLUMN 12 are obtained by selecting whichever value is the *larger* from either *Column* 6 or *Column* 11 (i.e. *Column* 12 = *Maximum* value from *Column* 6 and *Column* 11).

The values for COLUMN 13 are obtained by selecting whichever value is the *smaller* from either *Column* 7 or *Column* 10 (i.e. *Column* 13 = *Minimum* value from *Column* 7 and *Column* 10).

Where more or fewer screen sizes are used, Columns 3, 4 and 5 would be changed accordingly.

Generally, rounded figures are used as specification limits in Columns 3 and 4 and in Columns 12 and 13. The figures used in this table were selected to indicate more clearly the method.

*It will be noted that a very narrow specification by the "Passing and Retained" method gives a much wider specification by the "Total Percent Passing" method. This ability of the "Total Percent Passing" method to provide a narrow close control on the gradation, with reasonable margins on the screen sizes, is an important advantage of this method.

APPENDIX II

DO'S AND DON'TS OF BLASTING

DEFINITIONS

1. The term "explosives" as used herein includes any or all of the following: dynamite, black blasting powder, pellet powder, blasting caps, electric blasting caps, and detonating fuse.

2. The term "electric blasting cap" as used herein includes both instantaneous electric blasting caps and all types of delay electric blasting caps.

3. The term "primer" as used herein means a cartridge of explosives in combination with a blasting cap or an electric blasting cap.

WHEN TRANSPORTING EXPLOSIVES

1. DO obey all federal, state, and local laws and regulations.

2. DO see that any vehicle used to transport explosives is in proper working condition and equipped with a tight wooden or nonsparking metal floor with sides and ends high enough to prevent the explosives from falling off. The load in an open-bodied truck should be covered with a waterproof and fire-resistant tarpaulin, and the explosives should not be allowed to contact any source of heat such as an exhaust pipe. Wiring should be fully insulated so as to prevent short circuiting, and at least two fire extinguishers should be carried. The truck should be plainly marked so as to give adequate warning to the public of the nature of the cargo.

3. DON'T permit metal, except approved metal truck bodies, to contact cases of explosives. Metal, flammable, or corrosive substances should not be transported with explosives.

4. DON'T allow smoking or unauthorized or unnecessary persons in the vehicle.

5. DO load and unload explosives carefully. Never throw explosives from the truck.

6. DO see that other explosives, including detonating fuse, are separated from blasting caps and/or electric blasting caps where it is permitted to transport them in the same vehicle.

7. DON'T drive trucks containing explosives through cities, towns or villages, or park them near such places as restaurants, garages, and filling stations, unless it cannot be avoided.

8. DO request that explosive deliveries be made at the magazine or in some other location well removed from populated areas.

9. DON'T fight fires after they have come in contact with explosives. Remove all personnel to a safe location and guard the area against intruders.

WHEN STORING EXPLOSIVES

10. DO store explosives in accordance with federal, state, or local laws and regulations.

11. DO store explosives only in a magazine which is clean, dry, well ventilated, reasonably cool, properly located, substantially constructed, bullet and fire resistant, and securely locked.

12. DON'T store blasting caps or electric blasting caps in the same box, container, or magazine with other explosives.

13. DON'T store explosives, fuse, or fuse lighters in a wet or damp place, or near oil, gasoline, cleaning solution or solvents, or near radiators, steam pipes, exhaust pipes, stoves, or other sources of heat.

14. DON'T store any sparking metal or sparking metal tools in an explosives magazine.

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15. DON'T smoke or have matches, or have any source of fire or flame, in or near an explosives magazine.

16. DON'T allow leaves, grass, brush, or debris to accumulate within 25 feet of an explosives magazine.

17. DON'T shoot into explosives or allow the discharge of firearms in the vicinity of an explosives magazine.

18. DO consult the manufacturer if nitroglycerin from deteriorated explosives has leaked onto the floor of a magazine. The floor should be desensitized by washing thoroughly with an agent approved for that purpose.

19. DO locate explosives magazines in the most isolated places available. They should be separated from each other, and from inhabited buildings, highways, and railroads, by distances not less than those recommended in the American Table of Distances.

WHEN USING EXPLOSIVES

20. DON'T use sparking metal tools to open kegs or wooden cases of explosives. Metallic slitters may be used for opening fiberboard cases, provided that the metallic slitter does not come into contact with the metallic fasteners of the case.

21. DON'T smoke or have matches, or any source of fire or flame, within 100 feet of an area in which explosives are being handled or used.

22. DON'T place explosives where they may be exposed to flame, excessive heat, sparks, or impact.

23. DO replace or close the cover of explosives cases or packages after using.

24. DON'T carry explosives in the pockets of your clothing or elsewhere on your person.

25. DON'T insert anything but fuse in the open end of a blasting cap.

26. DON'T strike, tamper with, or attempt to remove or investigate the contents of a blasting cap or an electric blasting cap, or try to pull the wires out of an electric blasting cap.

27. DON'T allow children or unauthorized or unnecessary persons to be present where explosives are being handled or used.

28. DON'T handle, use, or be near explosives during the approach or progress of any electrical storm. All persons should retire to a place of safety.

29. DON'T use explosives or accessory equipment that are obviously deteriorated or damaged.

30. DON'T attempt to reclaim or to use fuse, blasting caps, electric blasting caps, or any explosives that have been water-soaked, even if they have dried out. Consult the manufacturer.

WHEN PREPARING THE PRIMER

31. DON'T make up primers in a magazine, or near excessive quantities of explosives, or in excess of immediate needs.

32. DON'T force a blasting cap or an electric blasting cap into dynamite. Insert the cap into a hole made in the dynamite with a punch suitable for the purpose.

33. DO make up primers in accordance with proven and established methods. Make sure that the cap shell is completely encased in the dynamite or booster and so secured that in loading no tension will be placed on the wires or fuse at the point of entry into the cap. When side priming a heavy wall or a heavyweight cartridge, wrap adhesive tape around the hole punched in the cartridge so that the cap cannot come out.

WHEN DRILLING AND LOADING

34. DO comply with applicable federal, state, and local regulations relative to drilling and loading.

35. DO carefully examine the surface or face before drilling to determine the possible presence of unfired explosives. Never drill into explosives.

36. DO check the borehole carefully with a wooden tamping pole or a measuring tape to determine its condition before loading.

37. DO recognize the possibility of static electrical hazards from pneumatic loading and take adequate precautionary measures. If any doubt exists, consult your explosives supplier.

38. DON'T stack surplus explosives near working areas during loading.

39. DO cut from the spool the line of detonating fuse extending into a borehole before loading the remainder of the charge.

40. DON'T load a borehole with explosives after springing (enlarging the hole with explosives) or upon completion of drilling without making certain that it is cool and that it does not contain any hot metal, or burning or smoldering material. Temperatures in excess of 150°F are dangerous.

41. DON'T spring a borehole near another hole loaded with explosives.

42. DON'T force explosives into a borehole or through an obstruction in a borehole. Any such practice is particularly hazardous in dry holes and when the charge is primed.

43. DON'T slit, drop, deform, or abuse the primer. DON'T drop a large size, heavy cartridge directly on the primer.

44. DO avoid placing any unnecessary part of the body over the borehole during loading.

45. DON'T load any boreholes near electric powerlines unless the firing line, including the electric blasting cap wires, is so short that it cannot reach the power wires.

46. DON'T connect blasting caps or electric blasting caps to detonating fuse except by methods recommended by the manufacturer.

WHEN TAMPING

47. DON'T tamp dynamite that has been removed from the cartridge.

48. DON'T tamp with metallic devices of any kind, including the metal end of loading poles. Use wooden tamping tools with no exposed metal parts, except nonsparking metal connectors for jointed poles. Avoid violent tamping. Never tamp the primer.

49. DO confine the explosives in the borehole with sand, earth, clay, or other suitable incombustible stemming material.

50. DON'T kink or injure fuse or electric blasting cap wires when tamping.

WHEN SHOOTING ELECTRICALLY

51. DON'T uncoil the wires or use electric blasting caps during dust storms or near any other source of large charges of static electricity.

52. DON'T uncoil the wires or use electric blasting caps in the vicinity of radio frequency transmitters, except at safe distances. Consult the manufacturer or The Institute of Makers of Explosives pamphlet on "Radio Frequency Hazards."

53. DO keep the firing circuit completely insulated from the ground or other conductors such as bare wires, rails, pipes, or other paths of stray currents.

54. DON'T have electric wires or cables of any kind near electric blasting caps or other explosives except at the time and for the purpose of firing the blast.

55. DO test all electric blasting caps, either singly or when connected in a series circuit, using only a blasting galvanometer specifically designed for the purpose.

56. DON'T use in the same circuit either electric blasting caps made by more than one manufacturer or electric blasting caps of different style or function, even if made by the same manufacturer, unless such use is approved by the manufacturer.

57. DON'T attempt to fire a single electric blasting cap or a circuit of electric blasting caps with less than the minimum current specified by the manufacturer.

58. DO be sure that all wire ends to be connected are bright and clean.

59. DO keep the electric cap wires or leading wires short-circuited until ready to fire.

WHEN SHOOTING WITH FUSE

60. DO handle fuse carefully to avoid damaging the covering. In cold weather warm slightly before using to avoid cracking the waterproofing.

61. DON'T use a short fuse. Know the burning speed of the fuse and make sure you have time to reach a place of safety after lighting. Never use less than two feet.

62. DON'T cut fuse until you are ready to insert it into a blasting cap. Cut off an inch or two to ensure a dry end. Cut fuse squarely across with a clean sharp blade. Seat the fuse lightly against the cap charge and avoid twisting after it is in place.

63. DON'T crimp blasting caps by any means except a cap crimper designed for the purpose. Make certain that the cap is securely crimped to the fuse.

64. DO light fuse with a fuse lighter designed for the purpose. If a match is used the fuse should be slit at the end and the match head held in the slit against the powder core. Then scratch the match head with an abrasive surface to light the fuse.

65. DON'T light fuse until sufficient stemming has been placed over the explosive to prevent sparks or flying match heads from coming into contact with the explosive.

66. DON'T hold explosives in the hands when lighting fuse.

IN UNDERGROUND WORK

67. DO use permissible explosives only in the manner specified by the United States Bureau of Mines.

68. DON'T take excessive quantities of explosives into a mine at any one time.

69. DON'T use black blasting powder or pellet powder with permissible explosives or other dynamite in the same borehole in a coal mine.

BEFORE AND AFTER FIRING

70. DON'T fire a blast without a positive signal from the one in charge, who has made certain that all surplus explosives are in a safe place, all persons and vehicles are at a safe distance or under sufficient cover, and that adequate warning has been given.

71. DON'T return to the area of any blast until the smoke and fumes from the blast have been dissipated.

72. DON'T attempt to investigate a misfire too soon. Follow recognized rules and regulations, or if no rules or regulations are in effect, wait at least one hour.

73. DON'T drill, bore, or pick out a charge of explosives that has misfired. Misfires should be handled only by or under the direction of a competent and experienced person.

EXPLOSIVES DISPOSAL

74. DON'T abandon any explosives.

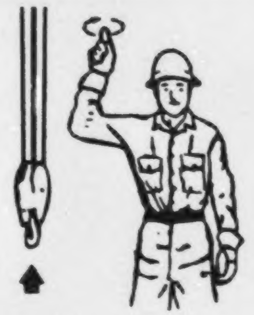
75. DO dispose of or destroy explosives in strict accordance with approved methods. Consult FM 5-25, the manufacturer, or follow The Institute of Makers of Explosives pamphlet on destroying explosives.

76. DON'T leave explosives, empty cartridges, boxes, liners, or other materials used in the packing of explosives lying around where children or unauthorized persons or livestock can get at them.

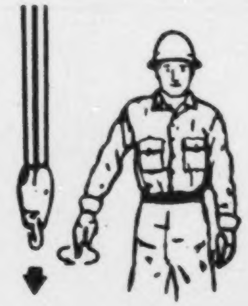
77. DON'T allow any wood, paper, or any other materials employed in packing explosives to be burned in a stove, a fireplace, or other confined space, or to be used for any purpose. Such materials should be destroyed by burning at an isolated location out of doors and no person should be nearer than 100 feet after the burning has started.

APPENDIX III

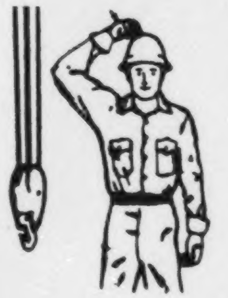
HAND SIGNALS



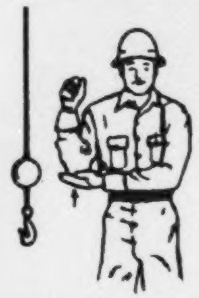
HOIST: WITH FOREARM VERTICAL, FOREFINGER POINTING UP, MOVE HAND IN SMALL HORIZONTAL CIRCLES.



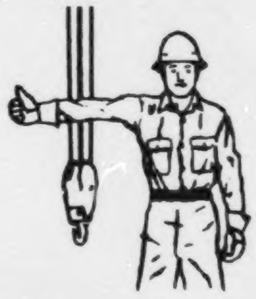
LOWER: WITH ARM EXTENDED DOWNWARD, FOREFINGER POINTING DOWN, MOVE HAND IN SMALL HORIZONTAL CIRCLES.



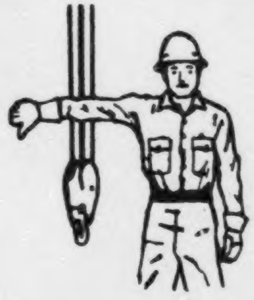
USE MAIN HOIST: TAP FIST ON HEAD, THEN USE REGULAR SIGNALS.



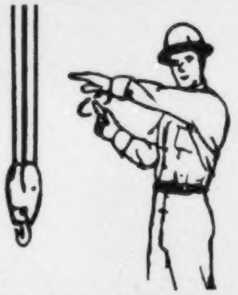
USE WHIP LINE: (AUXILIARY HOIST) TAP ELBOW WITH ONE HAND, THEN USE REGULAR SIGNALS.



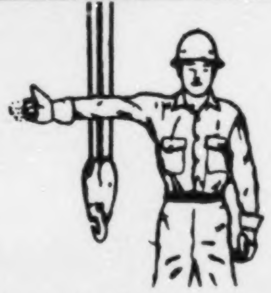
RAISE BOOM: ARM EXTENDED, FINGERS CLOSED, THUMB POINTING UPWARD.



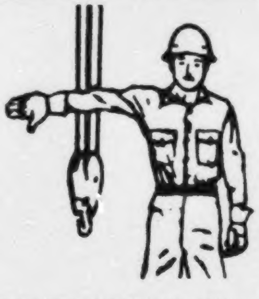
LOWER BOOM: ARM EXTENDED, FINGERS CLOSED, THUMB POINTING DOWNWARD.



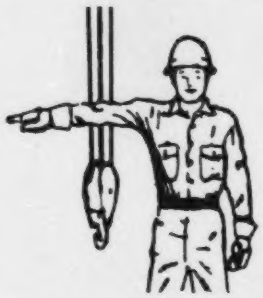
MOVE SLOWLY: USE ONE HAND TO GIVE ANY MOTION SIGNAL AND PLACE OTHER HAND MOTIONLESS IN FRONT OF HAND GIVING THE MOTION SIGNAL. (HOIST SLOWLY SHOWN AS EXAMPLE).



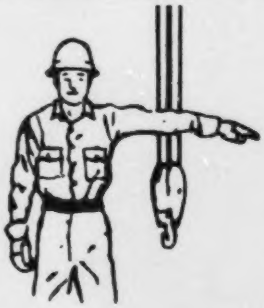
RAISE THE BOOM AND LOWER THE LOAD: WITH ARM EXTENDED THUMB POINTING UP, FLEX FINGERS IN AND OUT AS LONG AS LOAD MOVEMENT IS DESIRED.



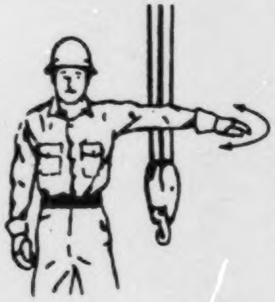
LOWER THE BOOM AND RAISE THE LOAD: WITH ARM EXTENDED, THUMB POINTING DOWN, FLEX FINGERS IN AND OUT AS LONG AS LOAD MOVEMENT IS DESIRED.



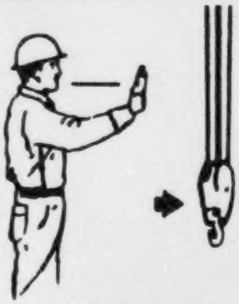
SWING: ARM EXTENDED POINT WITH FINGER IN DIRECTION OF SWING OF BOOM.



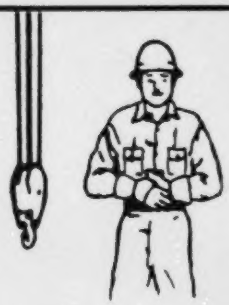
STOP: ARM EXTENDED, PALM DOWN, HOLD POSITION RIGIDLY.



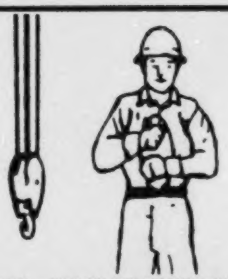
EMERGENCY STOP: ARM EXTENDED, PALM DOWN, MOVE HAND RAPIDLY RIGHT AND LEFT.



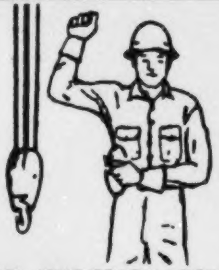
TRAVEL: ARM EXTENDED FORWARD, HAND OPEN AND SLIGHTLY RAISED, MAKE PUSHING MOTION IN DIRECTION OF TRAVEL.



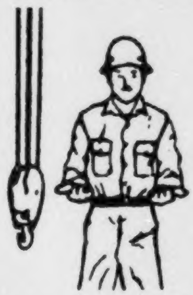
DOG EVERYTHING: CLASP HANDS IN FRONT OF BODY.



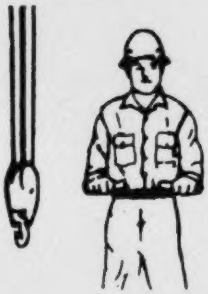
TRAVEL: (BOTH TRACKS) USE BOTH FISTS, IN FRONT OF BODY, MAKING A CIRCULAR MOTION, ABOVE EACH OTHER, INDICATING DIRECTION OF TRAVEL, FORWARD OR BACKWARD (FOR CRAWLER CRANES ONLY).



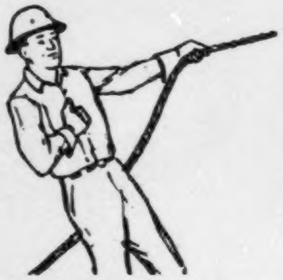
TRAVEL: (ONE TRACK) LOCK THE TRACK ON SIDE INDICATED BY RAISED FIST, TRAVEL OPPOSITE TRACK IN DIRECTION INDICATED BY CIRCULAR MOTION OF OTHER FIST, ROTATED VERTICALLY IN FRONT OF BODY (FOR CRAWLER CRANES ONLY).



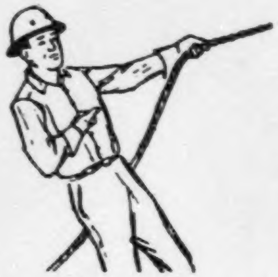
EXTEND BOOM: (TELESCOPING BOOM) BOTH FISTS IN FRONT OF BODY WITH THUMBS POINTING OUTWARD.



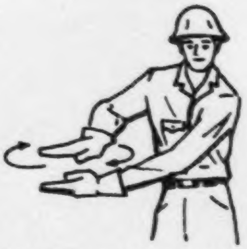
RETRACT BOOM: (TELESCOPING BOOM) BOTH FISTS IN FRONT OF BODY WITH THUMBS POINTING TOWARD EACH OTHER.



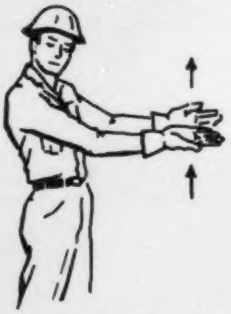
EXTEND BOOM: (TELESCOPING BOOM) ONE HAND SIGNAL. ONE FIST IN FRONT OF CHEST WITH THUMB TAPPING CHEST.



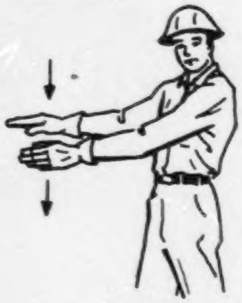
RETRACT BOOM: (TELESCOPING BOOM) ONE HAND SIGNAL. ONE FIST IN FRONT OF CHEST, THUMB POINTING OUTWARD AND HEEL OF FIST TAPPING CHEST.



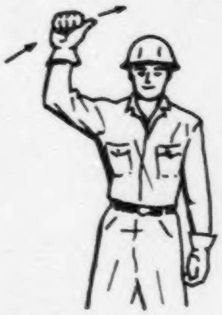
WHEN CUT, FILL OR HAUL ROAD IS TO BE DRAGGED OR BLADED, POINT TO THE AREA, THEN RUB PALMS OF HANDS TOGETHER INDICATING A SMOOTHING MOTION. APPLIES TO SCRAPERS, MOTOR GRADERS AND BULLDOZERS.



RAISE A LITTLE



LOWER A LITTLE



DUMP LOAD NOW: (START DUMPING AND SPREADING LOAD TO PROPER DEPTH IF GIVEN.)

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EQUIPMENT OPERATOR 1 & C

NAVEDTRA 10641-G

Prepared by the Naval Education and Training Program Development Center, Pensacola, Florida

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Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, EQUIPMENT OPERATOR 1&C NAVEDTRA 10641-G , is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

At this point you should be ready to answer the items in the assignment. Read each item carefully. Select the BEST ANSWER for each item, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Use only the self-scoring answer sheet designated for your assignment. Follow the scoring directions given on the answer sheet itself and elsewhere in this course.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the course disenrollment form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Naval Enlisted Manpower Personnel Classifications and Occupational Standards (NAVPERS 18068). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The qualifications for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068 and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 12 Naval Reserve retirement points, which will be credited upon satisfactory completion of the entire course. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve personnel. Credit cannot be given again for this course if the student has previously received credit for completing another Equipment Operator 1&C NRCC or ECC.

COURSE OBJECTIVE

In completing this NRCC, you will demonstrate a knowledge of the subject matter by correctly answering items on the following: administering an accident prevention program; organizing a battalion training program; managing the Personnel Readiness Capability Program; advanced base planning, embarkation, and project turnover; construction scheduling; grading, soil stabilization, and road surfacing; pit and quarry operations; well drilling; managing a construction and automotive equipment pool; and operating miscellaneous construction equipment, such as concrete transit trucks, slip-form pavers, pile hammers, and power earth augers.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was
1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	■	C	■	■	

TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without his commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	■	CC	■	■	

MATCHING ITEMS

Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Items in column B may be used once, more than once, or not at all. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	■	C	■	■	
s-4	C	■	■	■	
s-5	■	■	C	■	
s-6	C	■	■	■	

How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets

	1 T	2 F	3	4	
1	■	C	6	■	1
2	C	9	■	9	2
3	■	■	C	■	
4	CC	12	■	■	1

Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	[✓ 3.9]	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

Assignment 1

Administration

Textbook Assignment, NAVEDTRA 10641-G: Pages 1-1 through 1-28

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Indicate principles and techniques of administration or supervision in project planning and estimating. Textbook pages 1-1 through 1-19.

1-1. In planning a construction project, with which of the following estimates should you be concerned?

1. Equipment
2. Material
3. Manpower
4. Each of the above

1-2. Whether a construction project fails or succeeds may depend upon the accuracy of the calculations for each phase of development.

1-3. As petty officer in charge of construction work, you should confirm the planning for the next workday at the end of each workday.

1-4. To be an effective supervisor, which of the following factors should you consider in your day-to-day planning?

1. Keeping each crewmember fully occupied
2. Having enough equipment on hand to get the job done
3. Having enough supplies on hand to get started
4. All of the above

1-5. Assume the department head instructs you to complete a certain job by a certain time. Being responsible for a number of other jobs, you place a junior petty officer in charge of the crew assigned to this job. Who is responsible if the work falls behind schedule?

1. The senior crew member
2. The junior petty officer
3. You

1-6. As an estimator for a given project, you may be called upon to prepare which of the following estimates?

1. Quantities of materials required for the work to be done by the EO's
2. Quantities of materials required for work to be done by SEABEES other than the EO's
3. Man-hours required to complete the job
4. Each of the above

1-7. To estimate quantities of work elements and materials for a certain project, you must consult the

1. OICC
2. project drawings only
3. project specifications only
4. project drawings and specifications

1-8. When the project specifications differ from the drawings, what is the normal procedure to follow?

1. Obtain a new set of drawings and specifications
2. Follow the specifications
3. Follow the drawings
4. Consult the OICC

1-9. How do you correct an as-built drawing in case a change is made during construction?

1. Draw the change in red on the working drawing
2. List the change in the margin of the working drawing
3. Attach a change sheet to the working drawing
4. Each of the above

1-10. Which of the following methods is one of the best for reducing the errors made in the preparation of a quantity estimate?

1. Comparing the estimate with true quantities of the various items used on a similar job completed previously
2. Comparing the estimate with an independent estimate of the same project made by another person
3. Letting another person who is familiar with the project carefully check all computations
4. Reviewing each part of the estimate with the person who will do the work on that particular part of the project

1-11. How are work element estimates prepared?

1. Computing the man-hours required to complete one of the work elements of the project
2. Computing quantities of material required for one of the work elements of the project
3. Both 1 and 2 above
4. Computing all quantities of the various items of work shown or referenced on the drawings

1-12. When measuring quantities of materials for the work elements of a building project, you should usually begin by measuring the work elements on the

1. basement level
2. succeeding floor levels
3. foundation and footing plan
4. mechanical and electrical drawings

1-13. Assume that the concrete, reinforcing, architectural, structural, mechanical, and electrical drawings for a given project are drawn separately. In what order should you examine or work the drawings?

1. Concrete, reinforcing, mechanical, architectural, structural, and electrical
2. Concrete, reinforcing, structural, architectural, mechanical, and electrical
3. Mechanical, concrete, reinforcing, architectural, structural, and electrical
4. Mechanical, architectural, structural, concrete, reinforcing, and electrical

1-14. When you are measuring quantities on a drawing, what procedure is recommended to avoid duplications?

1. Start at the center and work towards the sides, check (✓) marking the particular work as you measure and record it
2. Start at one side and work toward the opposite side, color marking the particular work as you measure and record it
3. Start at the top and work down, lining out each piece of work as you measure and record it
4. Start at the bottom and work upward, lining out each piece of work as you measure and record it

1-15. You are assigned the job of preparing the work element summary sheet for a certain project. From what sources do you obtain the required information?

1. Drawings
2. Specifications
3. Worksheets
4. Job orders

1-16. When entering required details on a work element estimate summary, you should make it a practice to

1. put them in alphabetical order
2. record them so that its reviewers can understand what was taken off and how computations were made
3. list them according to their priorities
4. number them

1-17. "Materials takeoff" is another name for

1. material estimate
2. equipment summary
3. work element

1-18. In preparing a materials takeoff for a project, you should make a list of

1. the quantities of each work element required to construct the project
2. all materials placed in the project plus earth excavation and fill
3. the materials and quantities required to construct the project
4. all materials used on the project

- In answering items 1-19 through 1-21, refer to the textbook procedure for preparing a material estimate.

1-19. The first step of the procedure is to obtain which of the following from the work element estimate?

1. Work element quantity
2. Work element conversion unit
3. Quantity required
4. Waste and loss factor

1-20. Where do allowances for waste and loss appear in the procedure for preparing a material estimate?

1. On the worksheet before the work elements are converted into quantities of materials
2. On the worksheet after the work elements are converted into quantities of materials
3. On the recap sheet before the quantities are totaled
4. On the recap sheet after the quantities are totaled

1-21. After all entries are made, which of the following forms becomes the material estimate?

1. Material estimate worksheet
2. Material estimate recap worksheet
3. Work element estimate worksheet
4. Work element estimate summary sheet

1-22. As an estimator, you would determine if an increase in material waste or loss on a job is warranted.

1-23. Which of the following items of information is included on the equipment estimate for a construction project?

1. The number of days each piece of equipment will operate
2. The type of equipment required
3. The amount of equipment required
4. Each of the above

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1-24. How does an estimator obtain the required amount of operating time for a particular piece of equipment used on a construction project?

1. By dividing the quantity of work which the equipment is to perform by the estimated production rate per day
2. By dividing the quantity of work which the equipment is to perform by the production rate per day obtained from Navy school charts
3. By dividing the quantity of work which the equipment is to perform by 3/4 of the design capacity of the equipment
4. By making an estimate after considering work conditions, experience and previous performance of EO's, etc.

1-25. The number of pieces of each type of equipment required at any one time for a project is determined from the prepared equipment schedule.

1-26. Which of the following factors should you consider when preparing equipment estimates?

1. Type of material to be handled
2. Experience of operators
3. Condition of equipment and weather conditions
4. All of the above

1-27. What should be the estimator's attitude with respect to the various sources of information about production rates usually available in SEABEE operations offices?

1. Use these production rates because they are usually very accurate and readily adaptable to any project
2. Do not refer to these production rates when making estimates because every project is different
3. Use them, but make necessary adjustments after considering the basis on which these rates were established
4. Use only production rates contained in a government manual; disregard all other sources

1-28. How are the man-days listed on a typical manpower estimate for a construction project?

1. Total only
2. Total for each work element and of each rating
3. Total for the project and for each rating
4. Total for the project and for each work element, or the total of each rating for each work element

1-29. Which of the following is a basis for preparing a preliminary manpower estimate?

1. General description of a project
2. Computation of project area or other measure
3. Preselected man-days per unit
4. Each of the above

1-30. Refer to textbook table 1-1.

Assume that you must prepare a preliminary manpower estimate for the construction of an NCO club. The building will be 90 feet wide, 110 feet long, constructed of brick and concrete, and fully equipped. The project site is in an area where conditions are favorable for construction. How many man-days will be required to complete the club?

1. 1,920
2. 2,970
3. 5,940
4. 9,900

1-31. Refer to textbook table 1-2.

Assume that you must prepare a preliminary manpower estimate for the construction of an avgas fuel farm in an area where weather and building conditions are average. The project includes a 7,000-barrel capacity fuel tank; 750 feet of 3-inch fuel lines; two 10- by 15-foot pumphouses; 1,300 yards of overhead electric powerlines; and 2,000 yards of telephone lines. Approximately how many man-days will it take to build the avgas fuel farm?

1. 1,000
2. 1,055
3. 1,249
4. 1,500

1-32. Refer to textbook table 1-3.

Assume you are preparing a detailed manpower estimate for a pipeline project. The work element estimate shows that 3 miles of ditchline, 6 feet deep by 2 feet wide, are to be machine excavated. Approximately how many man-days are required for the excavation under average conditions?

1. 176
2. 125
3. 75
4. 25

1-33. Refer to textbook table 1-4 and textbook figure 1-7.

Assume you are to haul 3,000 tons of asphalt to a road project. Furthermore, a delay factor of 0.72 represents peak production with a minimum 50-minute hauling time. Approximately how many man-days are required for the haul?

1. 13.0
2. 21.6
3. 30.6
4. 72.0

1-34. To keep operations running smoothly, it is necessary to know about which of the following factors?

1. Materials flow
2. Supply procedures
3. Equipment deployment
4. Each of the above

1-35. What action should you take if the materials for a project fail to arrive on time?

1. Contact the supply department
2. Personally search for the materials
3. Appoint a junior petty officer to investigate
4. Notify the project officer

1-36. When materials, such as piping, are stowed at the jobsite, it is a good practice to segregate the materials according to

1. type only
2. length only
3. size only
4. type, length, and size

1-37. Who is responsible for the daily and weekly maintenance of the equipment used on a round-the-clock basis to complete a road project on schedule?

1. The shift equipment operator
2. The field maintenance crew
3. The project supervisor
4. Each of the above

1-38. When kept up to date, reports and records are helpful in doing which of the following tasks?

1. Plan or schedule upcoming projects
2. Compare current work progress to planned work progress
3. Check the performances of crewmembers
4. Each of the above

Learning Objective: Indicate principles and techniques of administering an accident prevention program. Textbook pages 1-19 through 1-26.

1-39. In establishing a safety organization, each unit of the NCF must develop an accident prevention program and enforce safe working practices.

1-40. The safety officer is responsible for formulating safety doctrine and policy for the battalion. The safety officer does so by which of the following means?

1. Conducting on-the-job analyses
2. Consulting with project supervisors
3. Both 1 and 2 above

1-41. In addition to assigning crewmembers to equipment operation, project supervisors are also responsible for crew safety, health, and physical welfare.

1-42. Working your plan for controlling the hazards of a job will help you do which of the following?

1. Upgrade production
2. Prevent accidents
3. Instill respect
4. Each of the above

1-43. How often should you hold a standup safety meeting at the project site?

1. Weekly
2. Biweekly
3. Monthly
4. Whenever an accident has been reported

1-44. Which of the following results should come out of a group discussion pertaining to an accident which happened on the job and resulted in an injury?

1. Kind of injury sustained
2. Ways of preventing the accident
3. Cause of the injury
4. All of the above

1-45. Regularly scheduled standup safety meetings must be kept interesting. You can help keep them from becoming dull by

1. letting your crew air their gripes at the meetings
2. exceeding the time limits you set for the meetings
3. having the same crewmember conduct all meetings
4. showing good motion pictures and other visual aids on suitable subject matter

1-46. What information is included in the periodic safety report that you submit to the safety chief?

1. Time spent at safety meetings
2. Attendance figures
3. Subject matter covered
4. Each of the above

1-47. In case of an accident to one of your crewmembers, you must write answers to the questions listed on OPNAV Form 5100/1.

● In answering items 1-48 through 1-51, refer to figures 1-8 through 1-11 of your textbook.

1-48. What block contains information pertaining to the means by which ANDERSON came in contact with the source of his injury?

1. 17
2. 18
3. 21
4. 22

1-49. What block contains information pertaining to the circumstances and events that caused ANDERSON to fall?

1. 17
2. 18
3. 21
4. 22

1-50. What block contains information pertaining to the condition that caused or contributed to ANDERSON's accident?

1. 17
2. 18
3. 21
4. 22

1-51. What block describes the nature of ANDERSON's injury?

1. 17
2. 18
3. 21
4. 22

1-52. The purpose for filling out sections 22 through 25 of the Accident Injury/Death Report (OPNAV 5100/1) is to

1. recommend corrective action
2. identify the principal unsafe condition or act that caused the accident
3. provide a detailed description of the accident
4. determine whether or not a formal investigation of the accident is required

1-53. Block 27 of the Accident Injury/Death Report (OPNAV 5100/1) should include

1. your description of the accident
2. your opinion as to whether or not the accident was caused by an unsafe act
3. your opinion as to whether or not the accident was caused by an unsafe condition
4. actions taken or recommended to be taken to prevent recurrence of an injury similar to the one being reported

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In answering items 1-54 through 1-57, select from column B the classification given to the condition in column A that caused, permitted, or contributed to an accident.

	A. Conditions or Actions	B. Classifications
1-54.	Allowed water, oil, or grease to accumulate on a working surface	1. Unsafe condition
		2. Unsafe act
		3. Unsafe personal factor
1-55.	Did not understand that goggles had to be worn	
1-56.	Hammered on chisel that had a mushroomed head	
1-57.	Mixed battery acid and water without wearing protective gear	

1-58. What is the main reason for completing the investigation of an accident involving an injured crewmember?

1. To assign responsibility for the accident to the proper individual
2. To determine the amount of liability for the accident that the crewmember should properly assume
3. To prevent accidents of a similar nature
4. Each of the above

Learning Objective: Recognize principles and techniques of inspecting new construction and existing structures.
Textbook pages 1-26 through 1-28.

1-59. Which of the following is a technique that will promote good human relations with those you must deal with?

1. Being rude and tactless
2. Being partial
3. Playing favorites
4. Criticizing without being offensive

1-60. As a construction inspector, your main responsibility is to make sure that

1. the work performed is of the highest standard of quality
2. the work is performed in accordance with the drawings and specifications for the project
3. every item required for the project is on hand before the work starts
4. you are tactful and courteous in your relations with your workers and your superiors

1-61. In cases where specific tolerances are NOT fixed, the inspector must be certain to

1. check workmanship for perfection
2. insure that work is within ±5 percent of drawing dimensions
3. insure that work is within ±10 percent of drawing dimensions
4. judge whether workmanship is the most suitable grade for the purpose

1-62. As a project nears completion, it is the inspector's responsibility to insure that the

1. material ordered for the project is used
2. items needed for completion of the project have actually been provided
3. number of crewmembers assigned to the project is reduced
4. crew leader changes the as-built drawings as appropriate

1-63. Seeing that personnel are wearing appropriate protective apparel, that materials are properly stowed, and that work areas are kept clean and orderly are items that an inspector should include when doing which of the following?

1. Supervising construction operations
2. Briefing the safety chief each week
3. Reporting to the operations officer each month
4. Each of the above

1-64. One of the inspector's responsibilities with regard to the use of unsafe equipment is to

1. consult the safety officer and report the findings
2. point out the defects to personnel utilizing this equipment in an attempt to reduce potential hazards
3. remove the defective or unsafe equipment from service immediately
4. report the findings at the next safety meeting

1-65. Which of the following requirements is essential to the achievement of maintenance standards?

1. Detecting faults and damages in buildings or other structures during inspection
2. Completing repairs as quickly and cheaply as possible
3. Each of the above

1-66. It is useless to look at locally prepared forms for information that can help you carry out a building inspection.

Assignment 2

Administration (continued): Techniques of Supervision

Textbook, NAVEDTRA 10641-G: Pages 1-28 through 1-43 and 2-1 through 2-6

Learning Objective: Describe and prepare official Navy letters, messages, and memoranda. Textbook pages 1-28 through 1-34.

2-1. The copy of a standard naval letter prepared by Alfa Company for the CO's signature is usually a

1. smooth copy
2. rough copy
3. perfect copy

- In answering items 2-2 through 2-4, refer to textbook figures 1-12 and 1-13.

2-2. Which of the following lines of the standard naval letter may NOT be required in all correspondence being prepared?

1. "To" line
2. "From" line
3. "Subject" line
4. "Identification Symbol" line

2-3. In a standard naval letter, which of the following abbreviations is NOT correct?

1. Ref:
2. Encl:
3. Sub:

2-4. In a standard naval letter, which of the following formats is optional?

1. Spelling out or abbreviating the month
2. Stamping or typing the date
3. Either option 1 or 2 above or both
4. Placing the identification symbols where they fit best

2-5. Who is responsible for the finished correspondence prepared by you?

1. Drafting officer
2. Department head
3. Duty officer
4. You

2-6. In correspondence requiring a classification, where is it shown?

1. Left-hand margin
2. Right-hand margin
3. Top of the page
4. Top and bottom of the page

2-7. In preparing a naval letter, you are NOT allowed to cover two or more subjects even though they are closely related.

2-8. Which paragraph, if any, of a 3-paragraph naval letter should state the purpose of the letter?

1. First
2. Second
3. Third
4. None

2-9. In answering another letter, you should refer to it in the last paragraph of your letter.

2-10. As a writer of official correspondence, which of the following guidelines must you follow?

1. Maintain continuity when passing from one unit to another
2. Arrange your units in satisfactory order
3. Complete each unit before moving to the next
4. Each of the above

2-11. Which of the following is a poor practice in preparing a naval letter?

1. Repeating yourself
2. Using introductory phrases
3. Deleting intensive words
4. Cutting down on the use of big words

2-12. When a memorandum is typed on a plain sheet of bond paper, the word "memorandum" must appear on the sheet. This word is typed in as follows:

1. capital letters at the right margin above the "from" line
2. capital letters at the left margin above the "from" line
3. lowercase letters, two spaces below the "subject" line
4. lowercase letters between the "from" and "to" lines

2-13. What is the chief purpose of the format of a speedletter?

1. To help disseminate information within the Navy Directives Issuance System
2. To enable urgent correspondence to be transmitted by electrical means
3. To point out the necessity for priority handling
4. To make possible the transmission of classified documents

2-14. Speedletters are usually typewritten in the manner of a naval letter EXCEPT when

1. identifying blocks are used
2. enclosures are listed
3. time is critical
4. they are classified

2-15. Who authorizes the transmission of a message?

1. The drafter
2. The originator
3. The releasing officer
4. Each of the above

2-16. What format correctly expresses a date-time group in a naval message?

1. 07 DEC 79 @ 1330
2. 07 DEC 79; 1:30 P.M.
3. 071330Z DEC 79
4. DEC 071330Z 79

2-17. At most, how many spaces and characters are there per line of text in a naval message?

1. 49
2. 57
3. 69
4. 98

2-18. Of the following punctuation marks, which is NOT used in a naval message?

1. *
2. ?
3. &
4. /

Learning Objective: Point out fundamentals of organizing a battalion training program and managing the Personnel Readiness Capability Program. Textbook pages 1-34 through 1-43.

2-19. On which of the following factors does a battalion training program depend?

1. Available training facilities
2. Experience and previous training of personnel
3. Operational commitments
4. All of the above

2-20. The planning and carrying out of trainer programs calls mainly for the combined efforts of the

1. company training officers and the battalion training officer
2. petty officers, the company training officers, and the battalion training officer
3. petty officers, the company commanders, and the battalion training officer
4. petty officers, the company training officers, and the battalion commanding officer

2-21. What is the ideal relationship between training and construction schedules?

1. Training should never be undertaken when there is an actual construction job to be accomplished
2. Construction should not be scheduled until thorough training has been achieved
3. The demands of both must be considered, with emphasis on training when conflict in the demands arises
4. Both must be considered, with the completion of essential construction operations given priority

2-22. The purpose of the Personnel Readiness Capability Program is to provide accurate up-to-date personnel information that will enable the NCF to

1. schedule day-to-day work assignments for individual crewmembers
2. To combine all the information relevant to the planning and scheduling of project functions into a single master plan
3. increase its capabilities to plan, make decisions, and control

● Use the following alternatives in answering items 2-23 through 2-27.

1. Individual General Skills
2. Individual Rating Skills
3. Military Skills
4. Crew Experience (Skills)

2-23. Skills related to two or more ratings which are primarily nonmanipulative are classified as

2-24. Skills you acquired as a result of working with others on a particular project are normally classified as

2-25. Skills you acquired as a result of training for combat are broadly classified as

2-26. Nontechnical skills you acquire by participating in a cross-rate training program are generally classified as

2-27. Technical skills specifically related to one of the Construction ratings are classified as

2-28. What management tool should you use in collecting crewmember skill data?

1. Volume 1, PRCP Skill Definitions
2. PRCP Interviewer's Standards and Guides
3. Matrix Numbers 1 and 2
4. Section II, Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards

2-29. If you collect any information through observation or interview concerning an individual's skills, you must send it to FACSO, Port Hueneme on

1. an IBM card
2. a transcript master form
3. a 3 x 5 card
4. a message form

2-30. If you are in doubt about the proper methods to use in processing PRCP data, you should check with the

1. Public Works Officer
2. Security Officer
3. Chief Staff Officer
4. Training Officer

2-31. Before conducting an individual rating skill interview, what must you do?

1. Review the appropriate section of the Occupational Standards Manual
2. Prepare an interviewees service record
3. Prepare an interviewees checkoff sheet
4. Learn as much as you can about the skills and tasks explained in the interviewing guides

2-32. Refer to textbook figure 1-17. For which task or tasks must you interview a crewmember to see if the member is qualified to skill level 526.2.02?

1. 526.1.01
2. 526.1.02
3. 526.2.01
4. Each of the above

2-33. In introducing the skill material to an interviewee, you start by reading the skill definition

2-34. A typical task with task elements and related action statements is illustrated in textbook figure 1-19. At what task element must the interviewee apply all action statements?

1. 526.1.01
2. 526.2.02
3. 526.1.03
4. 526.2.04

● In answering items 2-35 through 3-38, assume you are an PRCP interviewer and are interviewing personnel for particular skill levels. Each item is to be judged true or false.

2-35. You should explain the purpose of the interview to each interviewee.

2-36. You should explain that your interviewees should not be embarrassed if they do not know everything that is expected of them about a specific skill level.

2-37. You should first read the task element, then the action statements to each interviewee.

2-38. You should stimulate the interest of each interviewee by asking questions pertaining to related tasks not listed in the guides.

Learning Objective: Describe principles and techniques of supervision. Textbook pages 2-1 through 2-6.

2-39. One of the meanings of supervision is overseeing and directing the work of others.

2-40. Which of the following steps should you take in organizing a road construction project?

1. Study the situation
2. Plan the steps for its completion
3. Check for crew availability and experience
4. All of the above

2-41. As the supervisor of an earthwork project, you should delegate as much responsibility as possible, but retain basic authority over all operations in progress.

2-42. Delays in the use of construction equipment and personnel indicate the need for more

1. echeloning
2. delegating
3. coordinating
4. layering

2-43. As the supervisor of equipment operations, you are responsible for which of the following?

1. Insuring that the equipment is used efficiently
2. Seeing that each job in process is within specifications
3. Insuring that your personnel are giving their best efforts
4. All of the above

2-44. When checking for dozer efficiency, you insure that operators maintain a maximum haul distance of NOT more than

1. 100 feet
2. 200 yards
3. 300 feet
4. 400 yards

2-45. By what means, if any, can you eliminate the bottlenecks that occur on a project?

1. Shifting or adding equipment
2. Improving facilities
3. Either 1 or 2 above or both
4. None

2-46. In which of the following ways can you control assigned jobs?

1. Setting job priorities
2. Utilizing operator skills
3. Determining time frames
4. All of the above

2-47. How often is preventive maintenance on construction equipment performed by an operator to enable the project to continue on schedule?

1. Daily only
2. Weekly only
3. Daily and weekly
4. Monthly

2-48. Liaison between operators and maintnance personnel is a must when repairs or major maintenenace is beyond the scope of the operators.

2-49. Which of the following practices should help you improve the morale of your crewmembers?

1. Being fair in dealing with them
2. Allowing them to set their own start times
3. Permitting them to secure early
4. Allowing them to operate equipment carelessly

2-50. Which of the following should you consider as a means of improving the morale of your crew?

1. Provide good working conditions
2. Stress the importance of their assignments to the overall project
3. Allow work crews to compete with one another
4. All of the above

2-51. You can earn the respect of your crews by providing good supervision and proper direction and setting a good example.

2-52. The priorities, patterns, and tempo of a battalion training program are usually established by the

1. Commanding Officer
2. Naval Education and Training Command
3. Chief of Naval Operations
4. CONCBPAC/COMCBLANT staff

2-53. The battalion training plan and organization must NOT interefere with construction schedules as set forth by the deployment operation order.

2-54. What happens to a crewmember's PAR upon duty transfer?

1. It is destroyed
2. It accompanies his or her service record
3. It is mailed to the next duty station

2-55. What factor determines the starting point for training a crewmember to do a certain job?

1. Inventory of his or her skills
2. Analysis of skills needed for the job
3. Time it takes to complete the job

2-56. As a supervisor, what kind of training are you most likely to conduct?

1. Formal
2. On-the-job
3. Military

2-57. Cross training of your crewmembers is valuable because it tends to develop

1. teamwork
2. group morale
3. individual capabilities

2-58. Being able to recognize a new crewmember's anxiety on the job, you are showing a quality called

1. know how
2. can-do spirit
3. empathy
4. leadership

2-59. If needed by your crew, formal training is usually scheduled when?

1. After normal working hours
2. During periods of enforced nonwork
3. Before a special operation is started
4. Each of the above

2-60. All of the following are good teaching practices EXCEPT

1. stressing the use of correct terminology and technical language
2. arranging teaching material systematically
3. allowing for much repetition and overlapping
4. insuring that instructional materials are complete

2-61. What type of subject matter is a teacher concerned with when the objective is to provide specific facts and terminology?

1. Knowledge
2. Attitude
3. Skill

2-62. In addition to training your crewmembers and keeping records on their progress, you will also maintain records on the progress of your construction projects.

Assignment 3

Advanced Base Planning, Embarkation, and Project Turnover: Construction Scheduling

Textbook Assignment, NAVEDTRA 10641-G: Pages 3-1 through 3-9 and 4-1 through 4-20

Learning Objective: Point out principles in the use of the Naval Facilities Planning Guide. (NAVFAC P-437)
Textbook page 3-1.

3-1. Included among the contents of NAVFAC P-437, Volume I, are the

1. amounts of fuel required to operate components
2. sizes of crews it takes to operate facilities
3. drawings of facilities and assemblies
4. acres of land a facility occupies

3-2. Volume II of NAVFAC P-437 is a source of information for planning an advanced base component, facility, or assembly.

3-3. Material requirements for which of the following units are listed in NAVFAC P-437 by National Stock Number?

1. Facility
2. Assembly
3. Component
4. Each of the above

3-4. Which units should be ordered only in a mobilization situation with CNO approval?

1. Components
2. Facilities
3. Assemblies

3-5. How do you obtain fixtures that are NOT furnished with a facility or assembly listed in NAVFAC P-437?

1. Pick them up at a supply depot
2. Order them separately
3. Purchase them on the open market

Learning Objective: Recognize fundamentals of preparing materials and equipment for embarkation.
Textbook pages 3-2 through 3-5.

3-6. In case contingency support of a Naval Task Force is required, personnel of Alfa Company must be ready to redeploy within how many days?

1. One
2. Two
3. Five
4. Ten

3-7. Which of the following is a responsibility of Alfa Company's embarkation representative?

1. Liaison between all other battalion companies prior to deployment
2. Liaison between battalion embarkation staff on all matters of embarkation
3. Maintenance of all line items used in a redeployment
4. Inventory of all combat ready gear

3-8. At the staging area for an amphibious embarkation, Alfa Company personnel are expected to operate which, if any, of the following?

1. Lowboy trucks
2. Forklifts and wreckers
3. Small boats
4. None

3-9. When assisting the loadmaster in an air embarkation, you must be sure that each vehicle being airlifted is marked to show its

1. axle weights only
2. center of gravity only
3. gross weight only
4. axle weights, center of gravity, and gross weight

3-10. For each self-propelled vehicle being air embarked, to what extent are its fuel tanks usually filled?

1. One-quarter full to three-quarters full
2. Empty to one-quarter full
3. Three-quarters full to full

3-11. Vehicles assisting in loading or unloading in an air embarkation must be equipped with a

1. winch or pintle hook
2. towbar
3. dolly
4. fifth wheel

3-12. Who maintains the speed of a road convoy during movement?

1. Pace Setter
2. Maintenance Officer
3. Convoy Commander
4. Company Commander

3-13. Who is responsible for seeing that a convoy vehicle is repaired as necessary during a halt?

1. The vehicle operator
2. Shotgun rider
3. Train Maintenance Officer
4. Convoy Commander

3-14. Who has logistic responsibility for a road convoy?

1. Supply Officer
2. Convoy Commander
3. Trail Maintenance Officer
4. Alfa Company Commander

Learning Objective: Describe principles of coordinating and supervising an Alfa Company project turnover. Textbook pages 3-5 through 3-9.

3-15. Before an NMCB completes deploying, an advance party of the relieving battalion goes to the deployment site to take inventory.

3-16. Who conducts the camp, supply, and material inventories at the site of an NMCB that is completing its deployment?

1. Personnel of the NMCB only
2. Personnel of the relieving battalion only
3. Personnel of both battalions

3-17. The purpose of a BEEP is to provide a uniform procedure for doing which of the following?

1. Evaluating and accounting for the equipment, records, and correspondence of a deployed battalion
2. Equipping a battalion before it deploys
3. Conducting maintenance inspections three months after a battalion arrives on station

3-18. Who is responsible for insuring that a copy of the Equipment Evaluation Inspection Guide and a copy of the Attachment Evaluation Inspection Guide are prepared for each piece of equipment during a BEEP?

1. Onsite battalion personnel only
2. Relieving battalion personnel only
3. Onsite and relieving battalion personnel
4. COMCBPAC/COMCBLANT Equipment Office representative

3-19. What code is given to a piece of deadline equipment to indicate that the cost of repairing it would be about 40 to 60 percent of its acquisition cost?

1. X
2. E2
3. 03
4. R4

3-20. Where can you find information to guide you in using repair parts during a BEEP?

1. NAVFAC Instructions 11200.1 series
2. Battalion Regulations
3. COMCBPAC/COMCBLANT Instructions 4040.1 series
4. COSAL

3-21. By what means do the members of a relieving battalion BEEP team distinguish between organic and augment equipment?

1. Equipment Summary Sheets
2. Color-coded decals
3. Vehicle locator cards
4. USN registration numbers

3-22. A BEEP completion report is prepared and submitted by whom?

1. Personnel of the relieving battalion
2. Personnel of the deployed battalion
3. Representatives of COMCBPAC/COMCBLANT staff or equipment office

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Learning Objective: Recognize fundamentals of construction scheduling. Textbook pages 4-1 through 4-7.

3-23. Before work starts on a project, the supervisor is guided by a construction schedule that serves to

1. integrate all previous analysis and planning
2. determine the technical data for the project
3. show the sequence in which personnel, materials, and equipment are needed

3-24. During construction of a project, the construction schedule enables the supervisor to

1. verify the amounts of materials and equipment needed for the project
2. furnish data on the methods and techniques of construction operations
3. determine whether work items are on or behind schedule
4. consolidate the materials takeoff for a continuous flow of the production process

3-25. Which of the following statements regarding the uses of construction schedules is true?

1. They become useless when project plans and specifications are changed
2. They may serve as a basis for estimating material requirements
3. They may be used for preparation of progress reports
4. They are useless after completion of a project

3-26. After completion of a project, an analysis of the construction schedule should identify information that has a future use.

3-27. All of the following are included among the elements of scheduling work EXCEPT the

1. quantity of work to be done
2. number of pieces of equipment
3. unit of measurement
4. time required for each work item

3-28. In addition to the principles that scheduled operations can NOT exceed a unit's capacity and that they must follow the sequence of work, what other scheduling principle should a supervisor apply in developing a good construction schedule?

1. Use the analysis of completed projects as a basis for accurate scheduling
2. Prepare checklists to effect intelligent overall supervision of the project
3. Follow the best sequence of work items required for the particular job
4. Keep a balance between starting critical items at the earliest time and maintaining a continuous effort for each task

3-29. From what schedule(s) can you obtain the separate work elements of a project?

1. Deployment schedule only
2. Project schedule only
3. Deployment and project schedules

3-30. Approximately what percentage of the total project, shown in textbook figure 4-1, will have been accomplished, if at the end of May, project 1 was 43 percent complete, project 2 was 22 percent complete, and project 3 was 67 percent complete?

1. 34
2. 42
3. 52
4. 58

3-31. Refer to textbook figure 4-2. Approximately how many cubic yards were trenched and backfilled on the POL system at the end of July?

1. 858
2. 968
3. 1342
4. 1716

3-32. The first thing you should do in scheduling a project is to determine the construction sequences.

3-33. The completion of an access road is estimated to take 500 man-days. With a work force of 40, approximately how many workdays are scheduled to complete the project?

1. 5
2. 12
3. 18
4. 22

3-34. How often should you report work completed on your assigned project?

1. Daily
2. Weekly
3. Biweekly
4. Monthly

3-35. What construction report, if any, is usually made in narrative form?

1. Daily
2. Weekly
3. Monthly
4. None

Learning Objective: Indicate principles and techniques of network analysis.
Textbook pages 4-7 through 4-20.

3-36. By definition, network analysis is a

1. technique of program evaluation and review
2. means of preparing arrow diagrams
3. method of designing arrow diagram problems
4. system of planning, scheduling, and controlling construction projects

3-37. As a project supervisor, an arrow diagram should aid you in construction management because it

1. identifies the amount of spare time available for each of the work items, services, or tasks involved in a given project
2. enables you to visualize, at a glance, the sequence and interrelationships of the individual items of work, services, or tasks involved in a given project
3. provides a quantitative analysis, in graphic form, of the material required for a given project

● Use the following alternatives in answering items 3-38 through 3-43.

1. an activity
2. an arrow
3. a circle
4. an event

3-38. The starting point of an activity is referred to as

3-39. In the preparation of an arrow diagram, an activity is indicated by the use of

3-40. An event is depicted on an arrow diagram by

3-41. A service or task that is indicated on an arrow diagram is referred to as

3-42. On an arrow diagram, the starting point of an activity is depicted by

3-43. An individual item of work is represented on an arrow diagram by

3-44. How many (a) activities, and (b) events are shown in textbook figure 4-8?

1. (a) 6 (b) 6
2. (a) 6 (b) 7
3. (a) 7 (b) 6
4. (a) 7 (b) 7

3-45. Before the work represented by activity (3) - (5) in textbook figure 4-8 can start, which of the following activities must be completed?

1. (1) - (3) and (3) - (4)
2. (3) - (4)
3. (1) - (2) and (1) - (3)
4. (1) - (3)

3-46. If an arrow diagram for a given project is inaccurate and unrealistic, network analysis will prove unsatisfactory.

3-47. In arrow diagram development, what is indicated by the question "What activity must be completed before this one can start?"

1. An event into which the activity should enter
2. An event from which to start the activity
3. The critical activities and events of the diagram
4. Only the critical activities of the diagram

3-48. You have established the starting point for a new activity on an arrow diagram. Which of the following questions should be answered in order to establish its termination point?

1. Is this a critical activity?
2. What is the estimated duration of this activity?
3. What activities must be accomplished before this one can proceed?
4. What activities cannot proceed if this one is not completed?

3-49. Which of the following statements describes the relationship between activities E and F of textbook figure 4-14?

1. Both activities start at the same point
2. Each is an independent activity
3. Of the two activities, E requires more time than F for completion
4. Each of the above

3-50. In the preparation of an arrow diagram that involves work items done by several ratings, you should consult with responsible representatives to insure that these items are accurately and realistically described.

3-51. At most, how many activities may carry the same event number at both the tail and head of the arrow?

1. One
2. Two
3. Three

3-52. What type of activity should you insert in an arrow diagram that does NOT represent work performance?

1. Extension
2. Connector
3. Network
4. Service

3-53. In textbook figure 4-15, the work item SURVEY & STAKEOUT can also be called activity

1. (1) - (2)
2. (2) - (3)
3. (3) - (2)
4. (1) - (3)

3-54. When shown on an arrow diagram, a dummy activity serves to indicate

1. duration
2. cost
3. dependency of sequence
4. work

3-55. An arrow diagram can sometimes describe a time relationship.

3-56. Refer to problem 1 in the textbook. At what event does obtaining draintile start?

1. First
2. Second
3. Third
4. Fourth

3-57. In problem 2 of the textbook, obtaining the trencher is known as a

1. dependent activity
2. dummy activity
3. delivery activity
4. duration activity

3-58. The arrow diagram for problem 2 in the textbook describes the

1. dependency relationship only
2. time relationship only
3. dependency and time relationships
4. delivery activity

3-59. In arrow diagramming, you can help remember the assumptions made about an activity by putting them in writing.

3-60. Refer to problem 3 in the textbook. Which view of textbook figure 4-18 indicates the event for fine grade to be completed?

1. A
2. B
3. C
4. D

- Use the following alternatives in answering items 3-61 and 3-62.

1. establish dependency between nondependent activities
2. maintain the uniqueness of the I - J identification system
3. transfer dependency from dependent activities to nondependent activities
4. describe dependencies in such a way that nondependent activities are not shown as dependent

3-61. The dummy activity illustrated in textbook figure 4-19 is used to

3-62. In textbook figure 4-20, the dummy activity is used to

3-63. View B of textbook figure 4-20 is in error because it shows

1. fine grade depending on the completion of prefab forms
2. availability of a backhoe depending on the completion of prefab forms
3. fine grade and availability of backhoe depending on the layout and excavation

3-64. Refer to the dummy problem in the textbook. Which view of textbook figure 4-21 removes the assumption that placing gravel second half does NOT start until draintile is installed?

1. A
2. B
3. C
4. D

3-65. An estimate of the time it should take to complete each event of an arrow diagram is known as

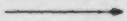
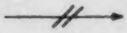
1. spare time
2. duration time
3. delayed time
4. critical time

3-66. The critical path of an arrow diagram is the

1. shortest path through the diagram
2. path through the diagram that requires the longest time to complete all the critical jobs
3. path through the diagram that includes all the longest individual work elements
4. path through the diagram consisting of the longest arrows

3-67. To determine easily the amount of time it should take to finish each individual activity in an arrow diagram, you assume that the usual number of crewmembers or pieces of equipment are available.

3-68. The critical path is usually identified by what symbol in an arrow diagram?

1. 
2. 
3.
4.

3-69. What usually happens in an arrow diagram when a critical path is shortened?

1. At least one other path becomes the critical path
2. Exactly two other paths become critical paths
3. The shortened path remains the critical path
4. No other path becomes the critical path

3-70. A special symbol is used on arrow diagrams to enable project managers to pick out a/an

1. earliest event
2. latest event time
3. shortest path
4. milestone

Assignment 4

Construction Scheduling (continued); Grading, Soil Stabilization, and Road Surfacing

Textbook Assignment, NAVEDTRA 10641-G: Pages 4-20 through 4-39 and Pages 5-1 through 5-21.

Learning Objective (continued):
Indicate principles and techniques of network analysis.
Textbook pages 4-20 through 4-31.

4-1. In using an arrow diagram, you can find the earliest time that an event can occur by adding the durations of the activities on the

1. paths parallel to the critical path
2. longest path leading up to the event
3. shortest path leading from the event

4-2. Refer to textbook figure 4-25. Of the symbols shown, which designates the latest event time?

1. ⊙
2. └
3. △
4. □

4-3. The earliest and latest event times for an activity will differ in the case where it is NOT on the critical path of an arrow diagram.

4-4. Refer to textbook figure 4-26. What event in the arrow diagram shows that waterproofing the arch and installing the ventilator are completed?

1. 10
2. 12
3. 16
4. 17

4-5. How should you calculate the latest start time for an activity shown in textbook figure 4-26?

1. Work from right to left, subtracting job duration from the preceding latest event time
2. Work from left to right, adding job duration to the preceding earliest event time
3. Either 1 or 2 above
4. Work from left to right, adding job duration to the preceding latest event times

4-6. What name is given to the spare time made available to perform a task shown on an arrow diagram?

1. Flex
2. Slack
3. Critical
4. Droop

4-7. By subtracting both the duration and earliest event time at the tail of the arrow from the latest event time at the head of the arrow of any activity, you can calculate the

1. start time
2. finish time
3. slack
4. duration

4-8. What, if anything, might happen should you change the slack of the earliest and latest event times of a fully developed arrow diagram?

1. Insufficient use is made of crew and equipment
2. Another critical path might develop
3. The job becomes inflexible
4. Nothing

4-9. Refer to textbook figure 4-26. Because of the slack in it, which activity can be scheduled to end the day before critical activity (17) - (18) begins?

1. (1) - (6)
2. (11) - (15)
3. (11) - (18)
4. (16) - (18)

4-10. How was time saved for critical path activity (3) - (5) of textbook figure 4-26?

1. By taking advantage of slack
2. By preparing a timetable
3. By counting weekends as project days
4. Each of the above

4-11. Which of the following events may lead to the addition of new activities to an arrow diagram?

1. Delayed material delivery
2. Manpower shortage
3. Design modification
4. Each of the above

4-12. Two or more activities that start on the same date are placed on the project schedule according to the amount of slack in them.

4-13. After you prepare a preliminary schedule of activities like the one in textbook figure 4-31, your next step is to transfer the given values to a

1. work report
2. bar chart
3. 3 x 5 card

4-14. When splitting work elements to make maximum use of manpower, you should check the arrow diagram for which of the following purposes?

1. To calculate amount of time saved
2. To determine the effect that splitting has on subsequent activities
3. To determine that effect of splitting on preceding activities
4. To calculate slack

Learning Objective: Apply principles of computing earthwork volumes and preparing mass diagrams. Textbook pages 4-31 through 4-39.

4-15. All of the following materials are included in earthwork computations EXCEPT

1. imported stabilization materials
2. stripped top soil
3. base course or paving materials
4. corrected cut and fill quantities

4-16. Earthwork computations are required regardless of the nature of the terrain or work situation.

4-17. It is necessary to plot cross sections of earthwork volumes at an intermediate space between stations whenever which of the following conditions occurs?

1. A roadway or taxiway is curved
2. There is a distinct change in the slope along the centerline
3. The earthwork changes from cut to fill
4. Each of the above

4-18. Of the following methods of determining plotted cross section areas, which yields the most accurate results?

1. Counting the squares
2. Trapezoidal
3. Planimeter
4. Either 2 or 3 above

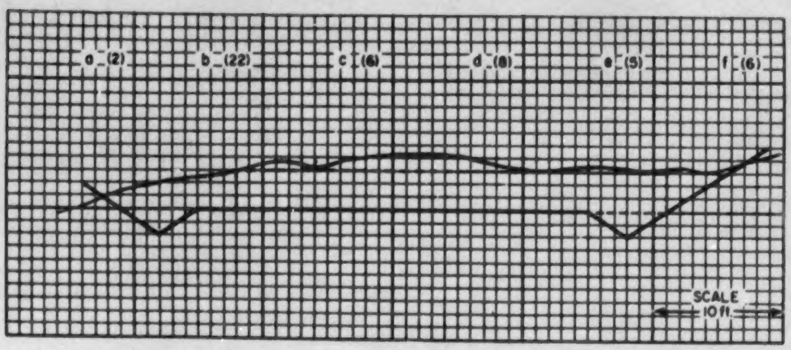


Figure 4A

4-19. The heavy bottom line in figure 4A represents a cross sectional view of the base level to which soil must be removed for a roadbed. What is the approximate end area in square feet of the volume of soil to be removed?

1. 118
2. 128
3. 138
4. 148

4-20. Suppose that you must remove soil for a roadbed from a surface similar in contour to that illustrated in figure 4A. You find that the two end cross sections, which are 100 feet apart, have areas of 115 square feet and 125 square feet, respectively. About how many cubic yards of soil will it be necessary to remove?

1. 345
2. 445
3. 545
4. 645

4-21. Assume that the areas of the cross sections in the preceding item are 128 square feet and 135 square feet, respectively. The distance between the stations at which the cross section areas are located is 80 feet. About how many cubic yards are in the space between the two cross sections?

1. 290
2. 340
3. 390
4. 440

4-22. The area of A_m in the prismoidal formula for the precise computation of volumes can be determined by

1. averaging the values A_1 and A_2
2. finding the sum of A_1 and A_2
3. finding the difference between A_1 and A_2
4. counting the squares on the cross section located halfway between A_1 and A_2

4-23. In the excavation and filling operations of a road building project, when is the limit of economic haul reached?

1. When the cost of haul exceeds the cost of excavation
2. When the cost of excavation exceeds the cost of haul
3. When the cost of haul equals the cost of excavation
4. When the cost of excavation increases as the cost of haul decreases

4-24. By definition, a free haul is one NOT costing extra since the distance traveled is less than

1. 100 feet
2. 200 feet
3. 300 feet
4. 500 feet

4-25. Which of the following is the first step in making a mass diagram?

1. Plotting algebraic sums of cuts and fills
2. Tabulating cumulative yardage
3. Balancing cuts and fills
4. Drawing the profile

4-26. Inspect the mass diagram of textbook figure 4-36 and approximate the volume of earthwork lying between stations 12 + 00 and 14 + 00.

1. 400 cu yd of borrow
2. 600 cu yd of waste
3. 800 cu yd of cut
4. 800 cu yd of fill

4-27. In textbook figure 4-36, the maximum point on the curve at station 3 + 50 corresponds to a section where the

1. yardage changes from fill to cut
2. yardage changes from cut to fill
3. volumes of borrow and waste are equal

4-28. Between which of the following stations in textbook figure 4-36 is the cut outside the limit of economical haul distance?

1. 0 + 00 and 1 + 00
2. 1 + 00 and 2 + 00
3. 1 + 00 and 3 + 00
4. 2 + 00 and 3 + 50

4-29. Between which stations in textbook figure 4-36 is the volume of the cut equal to the volume of the fill?

1. 13 + 00 and 14 + 50
2. 13 + 00 and 17 + 00
3. 14 + 00 and 18 + 50
4. 14 + 00 and 20 + 00

Learning Objective: Point out techniques that improve the efficiency of grading operations. Textbook pages 5-1 through 5-4.

4-30. When grading distances of less than 1,000 feet, which of the following procedures should the operator follow?

1. Always turn the grader for successive passes
2. Always back the grader up for each successive pass
3. Back blade each time you back up
4. Make a pass on the opposite side of the project

4-31. Which of the following machines is best suited for maintaining haul roads?

1. Towed scraper
2. Motorized scraper
3. Bulldozer
4. Grader

4-32. Construction operations are hindered by rain, but road maintenance operations often can be performed best after a rain.

In answering items 4-33 through 4-36, select from column B the speed range suitable for the operation in column A.

	A. Types of Operations	B. Speed Ranges
4-33.	Spreading	1. 2 mph
4-34.	Finishing	2. 2 to 3 mph
4-35.	Ditching	3. 3 to 5 mph
4-36.	Bank sloping	4. 3 to 6 mph

4-37. A haul road 6 miles long is to be leveled and reshaped with a motorized grader. You estimate that 12 passes will be needed to do the job. The first 6 passes are to be made in second gear at 2.6 mph; passes 7, 8, 9, and 10 in third gear at 3.2 mph; and passes 11 and 12 in fourth gear at 5.2 mph. Using an efficiency factor of 50 percent, approximately how long will it take to complete the job?

1. 35.2 hr
2. 37.3 hr
3. 45.2 hr
4. 47.2 hr

Learning Objective: Explain principles of road and runway compaction operations. Textbook pages 5-4 through 5-9.

In answering items 4-38 through 4-42, select from column B the type of road or runway foundation that must be compacted to meet the minimum density requirement in column A.

	A. Minimum Density Requirements		B. Types of Road and Runway Foundations
4-38.	95 percent below the top 12 inches of fill	1.	Bases, subbases, and improved subgrades
4-39.	95 percent for the top 12 inches of fill	2.	Cohesive subgrades
4-40.	100 percent of fill	3.	Cohesionless subgrades
4-41.	100 percent for the top 12 inches of fill		
4-42.	90 percent below the top 12 inches of fill		

4-43. In compaction work, a small test fill is sometimes constructed to obtain information about which of the following?

1. Thickness of the lift
2. Moisture content
3. Number of passes needed
4. Each of the above

4-44. When materials show resistance to compaction due to cohesion and granular interference, what type of action is needed?

1. Forging
2. Molding
3. Kneading

4-45. How much soil should be removed to meet compaction standards for subgrade cut sections?

1. 10 in.
2. 12 in.
3. 8 in.
4. 6 in.

4-46. When compacting pressure is too high, a soil will tend to

1. break up
2. cohere into a mass
3. increase in density
4. harden too quickly

4-47. What must you do to correct a soft or unstable area that develops during road construction?

1. Grade the area
2. Increase the moisture content of the area
3. Remove and reconstruct the area
4. All of the above

4-48. Which of the following properties affects the performance of a soil?

1. Grain size
2. Moisture content
3. Bearing capacity
4. Each of the above

4-49. Materials placed over subgrade soils are known as

1. low-bearing soils
2. high-bearing soils
3. base and subbase aggregates
4. coarse grained aggregates

4-50. Compared to base aggregates, subbase aggregates are placed deeper in a paved structure and may be lower in quality.

4-51. Which of the following types of soil and cement mixtures require the least amount of cement?

1. Hard soil-cement
2. Cement-modified soil
3. Plastic soil-cement

4-52. Cement-modified soils may be used for which of the following purposes?

1. Base courses and subbases
2. Highway fills
3. Treated subgrades
4. All of the above

4-53. Plastic soil-cement is used for paving highway ditch linings and erosion-control structures that roadbuilding equipment cannot reach.

4-54. The major portion of soil-cement is

1. water
2. soil
3. portland cement

4-55. Of the following materials, which should NOT be used as part of a soil-cement mixture?

1. Dead bituminous surface
2. Live bituminous surface
3. Gravel taken from a roadbed
4. Stone taken from a roadbed

4-56. The soils or soil combinations in a soil-cement mixture are stabilized through the

1. cohesion and internal friction of the soil
2. hydration of cement
3. friability of the mix

4-57. Whether a soil is generally suitable for use in soil-cement depends on its gradation and position in the soil profile.

4-58. Of the soils used in soil-cement construction, which type needs a higher cement content to harden adequately?

1. Sandy
2. Gravelly
3. Silty
4. Clayey

4-59. Soil samples are usually taken from a graded roadway by

1. obtaining a composite sample from various locations
2. trenching from the centerline to the outside shoulders, and to the depth of processing
3. using an auger on the surface

4-60. On a small soil-cement project, the best soil is usually sampled to find the cement content to stabilize the soil.

4-61. Which of the following soil-cement tests helps determine the lowest cement content that will harden the soil adequately?

1. Moisture-density
2. Wetting and drying
3. Freezing and thawing
4. Each of the above

4-62. Which of the following are subfactors of the major control factors in soil-cement construction?

1. Uniform mixing and extent of compacting
2. Proper finishing and amount of cement spread
3. Adequate pulverizing and curing
4. All of the above

4-63. Before the base course for a paved roadway can be completed adequately, which of the following areas must be able to support the compacting and finishing equipment?

1. Subbase
2. Subgrade
3. Surface course

4-64. Adequate hardening of mixed soil-cement depends mainly on which of the following steps in the processing of soil-cement?

1. Mixing the correct amount of water with soil
2. Mixing the correct amount of cement with soil
3. Pulverizing the soil to the proper degree
4. Curing the mixed soil-cement at least 7 days

4-65. According to specifications, what percent of a soil-cement mixture must pass the No. 4 sieve and the 1-inch sieve, respectively?

1. 80 percent and 10 percent
2. 80 percent and 100 percent
3. 100 percent and 10 percent
4. 100 percent and 80 percent

Learning Objective: Indicate procedures to follow in preparing and processing soil-cement for use in road construction projects. Textbook pages 5-13 through 5-21.

4-66. As the supervisor of a soil-cement road construction project, which of the following checks should you make during the preparation step?

1. Roadgrade and crown conditions
2. Equipment operating conditions
3. Stake locations
4. All of the above

4-67. Which of the following factors is least important in determining how many cement trucks and water trucks are needed for a given project?

1. In-place density of the soil
2. Anticipated rate of production
3. Length of haul
4. Condition of haul roads

4-68. What soil type requires little or no scarification or pulverization?

1. Silty
2. Clayey
3. Friable
4. Sandy

4-69. The maximum size of gravel or stone used for soil-cement is

1. 1 in.
2. 2 in.
3. 3 in.
4. 4 in.

4-70. To protect the soil-cement road project from the possibility of becoming "rained out" during construction, what construction procedures should the supervisor use?

1. Construct only one long section
2. Construct only one long and one short section
3. Construct several sections
4. Construct two short sections

4-71. Before cement is spread on clayey soil, what must the soil mixture be?

1. Below optimum
2. Slightly above optimum
3. Optimum

4-72. To produce a uniform cement spread with a mechanical spreader, which of the following conditions must exist?

1. Adequate traction
2. Constant speed
3. Constant level of cement in the hopper
4. All of the above

4-73. Assuming a roadway will use a cement content by volume of 12 percent, the specifications show the depth of the compacted soil-cement to be 5 inches, and the width of the spread 9 feet. The truckload of cement weights 8,250 pounds. What is the linear distance that the truck must travel to spread this required amount of cement?

1. 164.9 ft
2. 169.9 ft
3. 194.6 ft
4. 196.4 ft

4-74. To prevent arching of the cement within the surge tank or hopper, compressed air must be applied to maintain a pressure of

1. 2 to 4 psi
2. 2 to 5 psi
3. 4 to 2 psi
4. 4 to 4 psi

4-75. After running soil and cement separately through the plant for a period of time, the correct proportions are weighed and the cement meter adjusted accordingly. This procedure is known as

1. calibration
2. diversion
3. uniform cement discharge
4. uniform soil discharge

Assignment 5

Grading, Soil Stabilization, and Road Surfacing (continued)

Textbook Assignment, NAVEDTRA 10641-G: Pages 5-23 through 5-55

Learning Objective: (continued) Indicate procedures for preparing and processing soil-cement for use in road construction projects. Textbook pages 5-23 through 5-33.

5-1. You are to calculate a 2500-lb batch of soil-cement, in which the cement content, by weight of soil, is 8 percent; the optimum moisture content, by weight of soil plus cement is 10 percent; and the field moisture content of raw soil is 6 percent. Using these figures, what is the batch weight of cement based on dry soil?

1. 103.3 lb
2. 124.0 lb
3. 144.7 lb
4. 165.4 lb

5-2. When mixed in a batch-type plant, soil and portland cement should be dry.

5-3. Uniform windrows cause variations in cement content, moisture content, and roadway thickness.

5-4. A prepared soil windrow having the proper quantity of soil and cement must also contain the proper amount of water before compaction can be completed. Assume that a windrow is to be prepared in which the weight of soil per linear foot of windrow is 634 lb; the field moisture content of raw soil is 5 percent; the optimum moisture of soil-cement mixture is 10 percent; and the cement content required by weight is 8 percent. Assume further that the forward speed of the windrow mixing machine will be approximately 18 feet per minute. How many gallons of water per minute will be required?

1. 54.6 gal
2. 83.7 gal
3. 98.3 gal
4. 78.0 gal

In answering items 5-5 through 5-8, select from column B the type of mixing equipment that is used in soil-cement construction to perform the function in column A.

A. Functions

5-5. Picks up soil and cement and mixes them in place. Applies water and spreads mix

5-6. Mixes soil, cement, and water, leaving the mixed materials on the roadway for immediate compaction

5-7. Facilitates the storage, handling and proportioning of soil, cement, and water

5-8. Mixes prepared soil windrows with water and spreads the mix

B. Types of Mixing Equipment

1. Central mixing plant
2. Single-shaft traveling mixing machine
3. Miltiple-shaft traveling mixing machine
4. Windrow-type traveling mixing machine

5-9. Plans call for a soil-cement roadway to be constructed using the following specifications:

Mixing width..............12 ft
Compacted depth...........8 in.
Maximum density...........110 lbs per cu ft
Optimum moisture content..16%
Field moisture content
of raw soil....8%

When the mixing rate of the mixer is 25 feet per minute, how many gallons of water will be required per linear feet or per minute for a 1 percent moisture content to be maintained?

1. 7.40
2. 0.74
3. 19.80
4. 1.98

5-10. When processing mixed soil-cement with a mechanical spreader, the operator should NOT allow the spreader to do which of the following?

1. Spread while being loaded
2. Run empty after discharging a load
3. Spread until a uniform mixture is obtained
4. All of the above

5-11. What serves as a depth guide for placing a soil-cement mix in a lane adjoining the one you have just finished compacting?

1. Leaving a low berm of soil
2. Setting a marked depth pole
3. Leaving a narrow uncompacted ridge
4. Setting the spreader screed

5-12. Assume that you are to prepare a mix for soil-cement in a continuous-flow type of mixing plant according to the following specifications:

Cement content by weight............5%
Optimum moisture content
of soil-cement mixture............10%
Field moisture content
of raw soil..............6%

After 328.5 tons of soil enter the mixing drum, what is the combined weight of the soil and cement?

1. 10,330.2 lb
2. 10,846.7 lb
3. 10,900.0 lb
4. 11,516.6 lb

Learning Objective: Indicate procedures for compacting, finishing, and curing soil-cement on road construction projects.
Textbook pages 5-34 through 5-39.

5-13. The supervisor must insure that the compacting equipment used on soil-cement projects will exert proper pressure while NOT exceeding the bearing capacity of soil-cement mixture.

In answering items 5-14 through 5-17, select from column B the type of equipment used in soil-cement compaction to perform the operation in column A.

A. Operations

5-14. Generally used for initial compaction on all but the most granular soils

5-15. Compaction of granular soils containing little or no binder material

5-16. To press down or "set" rock particles and smooth out ridges during first rolling

5-17. Compaction of coarse sand and gravel soil-cement mixtures having little or no plasticity

B. Types of Compaction Equipment

1. Tandem steel-wheel roller
2. Three-wheel steel roller
3. Pneumatic-tired roller
4. Tamping roller

5-18. Which of the following conditions may cause a localized area to yield under compaction equipment?

1. Roller too heavy for the soil
2. Soil-cement mix too wet
3. Subsoil wet and unstable
4. All of the above

5-19. Why should compaction start immediately after soil-cement has been spread?

1. To obtain required densities readily
2. To minimize water evaporation
3. To keep daily production at a high level
4. All of the above

5-20. What type of roller is used to seal the surface during the final compaction operation?

1. Steel-wheeled
2. Pneumatic-tired
3. Sheepsfoot
4. Grid

5-21. Which of the following mixtures of soil-cement requires compaction with a tamping roller prior to finishing?

1. Very sandy mixture containing little or no fines
2. Coarse granular mixture
3. Mixture containing appreciable quantities of gravel and having little or no plasticity
4. Each of the above

5-22. When the specified thickness of the base course exceeds the depth that can be thoroughly mixed, moistened, compacted, and finished in one layer, soil-cement must be constructed in multiple layers.

5-23. Which of the following materials is used most extensively in the curing process of soil-cement?

1. Bituminous materials
2. Sandy materials containing little or no fines
3. Gravelly materials having little or no plasticity
4. Coarse granular materials

5-24. Soil-cement placed in cold weather should be protected against freezing for a minimum period of

1. 5 days
2. 7 days
3. 14 days
4. 15 days

5-25. What type of wearing course should be applied on a lightly traveled roadway having a soil-cement base course?

1. Single-surface bituminous-treated
2. Double-surface bituminous-treated
3. Multilayer bituminous-treated
4. Tack coat

Learning Objective: Point out properties of various bituminous surfacing materials used in the construction of roads and runways. Textbook pages 5-40 and 5-41.

5-26. Which of the following is a bituminous surfacing material?

1. Emulsion
2. Tar
3. Asphalt bitumen
4. Each of the above

5-27. A container of bituminous material showing the symbol AC indicates it contains which of the following?

1. Asphalt cutback
2. Asphalt cement
3. Asphalt emulsion
4. Anionic-cationic asphalt

5-28. When mixed with a petroleum distillate, an asphalt cement becomes an asphalt emulsion.

5-29. When used with asphalt cement, which of the following distillates allows for slow curing after application to a roadway?

1. Naphtha
2. Kerosene
3. Fuel oil
4. Gasoline

5-30. Of the following viscosity grades of an MC asphalt bitumen, which is considered the most fluid?

1. 30 to 60
2. 200 to 800
3. 800 to 1,000
4. 1,000 to 3,000

5-31. When added to asphalt cement, which of the following ingredients will produce an asphalt emulsion?

1. Water only
2. Soap only
3. Water and soap
4. Kerosene

5-32. What letter symbol denotes a rapid-setting asphalt emulsion?

1. CH
2. CM
3. RS
4. SS

5-33. An anionic asphalt emulsion will adhere with negatively charged aggregates to allow for a proper surfacing material mix.

5-34. What road tar symbol designates a hot tar?

1. RT 1
2. RT 2
3. RT 5
4. RT 9

5-35. An RTCB having a viscosity of 5 or 6 is which of the following tars?

1. Priming oil
2. Road tar
3. Road tar cutback
4. Cold tar

Learning Objective: Indicate uses of bituminous materials on road and runway wearing surfaces.
Textbook pages 5-41 through 5-43.

5-36. What is the normal temperature range that asphalt cements must be heated to allow for mixing with aggregates?

1. 77°F to 177°F
2. 250°F to 350°F
3. 350°F to 450°F
4. 450°F to 550°F

5-37. When applying asphalt cement in a warm climate, what penetration grade should you use?

1. Soft
2. Hard
3. Medium
4. Fluid

5-38. Refer to textbook table 5-7. When an RC 250 grade is required for a surface treatment, what distillate is used with asphalt cement?

1. Fuel oil
2. Kerosene
3. Naphtha
4. Solvent

5-39. Although asphalt emulsions are used for surface treatment, road and plant mixes, and crack and joint filling, their usage depends on which of the following factors?

1. Type of cutback used
2. Mixing ability
3. Setting rate
4. Both 2 and 3 above

5-40. Tar mixes are used in the construction of an airfield refueling apron when concrete is NOT available because they will NOT be dissolved by spilled petroleum products.

Learning Objective: Indicate tests for identifying bituminous materials in the field and techniques of testing and interpreting test results.
Textbook pages 5-43 through 5-48.

5-41. Field identification of bituminous materials found stockpiled in unmarked or incorrectly marked containers is necessary for which of the following reasons?

1. To determine the type of surface that can be constructed with the materials
2. To determine the type and quantity of equipment needed to handle the materials
3. To establish practices that will insure safe handling of the materials
4. Each of the above

5-42. Normally, what field test is used to differentiate unknown bituminous materials?

1. Heat-odor
2. Solubility
3. Water-mixing
4. Penetration

In answering items 5-43 through 5-46, select from column B the type of bituminous material that is identified by the solubility test result in column A.

	A. Solubility Test Results	B. Types of Bituminous Materials
5-43.	Sample contains small black globules	1. Asphalt
		2. Asphalt cement
5-44.	Sample contains a uniformly dark liquid	3. Emulsion
		4. Tar
5-45.	Sample contains stringy particles in suspension	
5-46.	Sample contains solid particles; will not pour	

5-47. What grade of asphalt is indicated by a field test in which the sharp point of a pencil penetrates the asphalt with difficulty?

1. Medium
2. Hard
3. Soft
4. Medium-hard

In answering items 5-48 through 5-51, select from column B the material that will pour similarly to an asphalt cutback having the viscosity in column A.

	A. Viscosities of Asphalt Cutbacks	B. Materials Flow Comparisons
5-48.	In the 30's	1. Molasses
5-49.	In the 250's	2. Light syrup
5-50.	In the 800's	3. Syrup
5-51.	In the 3,000's	4. Barely deform

5-52. When conducting a smear test, you should be able to identify a tacky asphalt cutback sample as

1. AC
2. RC
3. MC
4. SC

5-53. What is the identity of an asphalt cutback if the sample used in a smear test becomes sticky in a few minutes?

1. MC-800
2. RC-800
3. RC-3000
4. AC-3000

5-54. Suppose that during a prolonged smear test, the smear becomes a hard glazed spot. The test sample is identified as a/an

1. emulsion
2. tar
3. asphalt cement
4. asphalt cutback

5-55. By what test can you distinguish between a slow-curing and medium-curing asphalt cutback?

1. Pour
2. Heat-odor
3. Prolonged smear
4. Water-mixing

5-56. Which field test is used to identify an asphalt emulsion?

1. Heat-odor
2. Water-mixing
3. Flame
4. Either 2 or 3 above

5-57. It is necessary to determine the viscosity grade of an emulsion since there are many grades.

5-58. RT-12 is similar in consistency to what grade of asphalt cement?

1. 100 - 150
2. 200 - 300
3. 400 - 600
4. 800 - 3,000

5-59. After RTCB's are thinned with a very volatile material, what test is performed to identify grades 5 and 6?

1. Heat-odor
2. Solubility
3. Pour
4. Smear

Learning Objective: Indicate principles of constructing bituminous pavements with aggregate and other materials.
Textbook pages 5-48 through 5-52.

5-60. The purpose of aggregates in bituminous pavements is to

1. provide a smooth surface
2. provide for abrasive wear of the traffic
3. transmit the load from base course to the surface course

5-61. Particle size is the classification of a soil mass passing through a series of sieves.

5-62. When a sample of aggregate is being graded, what percent of aggregate passing the #4 and #10 sieves is retained on the #40 sieve?

1. 15
2. 17
3. 19
4. 43

5-63. During a sieve analysis, bituminous aggregate which passes the #4 sieve and is retained on the #200 sieve is referred to as

1. coarse aggregate
2. fine aggregate
3. granular dust filler
4. mineral filler

5-64. Aggregate testing sieves that are identified by mesh numbers are considered to be

1. larger than 3/8-inch in screen size
2. larger than 3/16-inch in screen size
3. smaller than 3/16-inch in screen size
4. smaller than 3/8-inch in screen size

5-65. The term "hot-mix" refers to a combination of heated uniform mix of aggregates and asphalt cement.

5-66. In addition to the quantity and grade of asphalt used, what other principal ingredient in terms of quantity affects the texture of the mix?

1. Coarse aggregate
2. Fine aggregate
3. Mineral dust
4. Each of the above

5-67. Which of the following course mixes contains the most mineral dust?

1. Base
2. Surface
3. Binder

5-68. The amount of asphalt cement in a hot mix of aggregate and asphalt is expressed as a percentage by weight of the

1. total mix only
2. dry aggregate only
3. total mix or dry aggregate

Learning Objective: Indicate principles of operating and maintaining a continuous-flow asphalt plant. Textbook pages 5-54 and 5-55.

5-69. The proper amount of aggregates for asphalt mixes is initially controlled by a uniform flow of the aggregate through

1. cold-feed adjustment
2. hot-feed adjustment
3. cold bin capacity
4. hot bin capacity

5-70. Which of the following means will insure a uniform flow of aggregates into the dryer?

1. Setting and securing the feeder gates after calibration
2. Maintaining segregated aggregate stockpiles
3. Keeping the feeder gates free of obstructions
4. All of the above

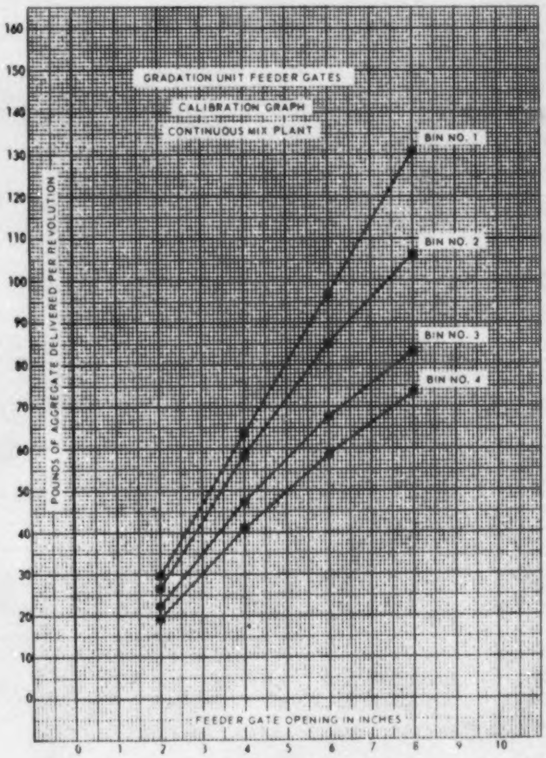


Figure 5A

- In answering items 5-71 and 5-72, refer to figure 5A.

5-71. How many pounds of aggregate per minute can be delivered from bin No. 2 with the feeder gate opening set at 6 inches?

1. 55
2. 75
3. 85
4. 96

5-72. Sixty-seven pounds of aggregate will be delivered if the feeder gate opening on bin No. 3 is set at a height of

1. 6 in.
2. 2 in.
3. 8 in.
4. 4 in.

5-73. What is the total pounds of aggregate delivered per minute from all bins with feeder gates open at 7 inches?

1. 334
2. 343
3. 346
4. 364

5-74. To provide coarse aggregate of 2-inch maximum size, the gate of cold aggregate feeder should be adjusted to a height of NOT less than

1. 5 or 6 in.
2. 2 1/2 or 3 in.
3. 3 or 4 in.
4. 4 or 5 in.

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Assignment 6

Grading, Soil Stabilization, and Road Surfacing (continued): Pits and Quarries

Textbook Assignment, NAVEDTRA 10641-G: Pages 5-56 through 5-69 and 6-1 through 6-13

Learning Objective: (continued) Indicate principles of operating and maintaining a continuous flow asphalt plant. Textbook pages 5-56 through 5-64.

6-1. A bin of cold feed aggregate is graded by

1. matching a sample of aggregate with a previously marked sample
2. running a sieve analysis
3. measuring the rate of aggregate to the fines
4. noting the progressive thickness of the fines

6-2. Which of the following factors affect the time required for the aggregate to pass through the dryer?

1. Slope of the cylinder and cylinder speed
2. Length, arrangements, and number of flights
3. All of the above

6-3. When very wet aggregate is passing through the dryer, what corrective measure should be taken?

1. Increase dryer heat
2. Reduce aggregate flow
3. Either 1 or 2 above
4. Increase the drum angle

6-4. When aggregate particles show signs of an oily coating after leaving the dryer, what adjustment is needed?

1. Decrease the amount of fuel oil or increase the blower or draft air
2. Decrease blower or draft air pressure
3. Increase the amount of fuel oil
4. Increase the amount of natural gas

6-5. An aggregate temperature-measuring device should be installed in the dryer discharge for plant control purposes.

6-6. When used in a continuous-flow asphalt plant, the dust collector serves which of the following purposes?

1. Draws off dust particles from the dryer
2. Allows for the heavier dust particles to be carried to the lower outlet of the collector
3. Both 1 and 2 above
4. Reduces air pollution

6-7. What determines the amount of dust from the dust collector that can be returned to the plant?

1. Combined grading of finished mix
2. Mix specifications
3. Either 1 or 2 above
4. Moisture content

6-8. Refer to table 5-8 of your textbook. How many tons per hour will pass over the 3/4-inch screen measuring 56 square feet?

1. 140 tons
2. 190 tons
3. 230 tons
4. 265 tons

6-9. Screening effectiveness is improved by using

1. a ball-deck to decrease choking
2. screens having small wire diameter
3. the full width of screen for uniform distribution
4. all of the above

6-10. Carryover of aggregates that pass over the plant hot screens is caused by which of the following conditions?

1. Nonregulation of the cold feed material
2. Dirty screens
3. Incorrect sieve analysis
4. All of the above

6-11. What means will prevent intermingling of the aggregates within the hot bins?

1. Tight partitions
2. Bins free of holes
3. Bins of sufficient height
4. All of the above

6-12. What means will prevent the buildup of aggregate fines in the hot bin corners?

1. Aerating from time to time
2. Welding fillet plates in the corners
3. Both 1 and 2 above

6-13. A sample of hot aggregate should be obtained from which of the following locations in a continuous-type plant?

1. Scalping screens
2. Overflow vents
3. Feeder gates
4. Dryer

6-14. The position of the sample device in the stream of aggregate materials leaving a bin of a continuous-type plant affects the sampling of the material.

6-15. What function does the vertical slot in the asphalt return line serve in asphalt heating and circulation?

1. Breaks the vacuum in the line upon reversing the asphalt pump
2. Allows for the circulation of asphalt through the feeding and storage system
3. Prevents oxidation of the asphalt
4. Provides a means of sampling asphalt

6-16. The temperature of the aggregates controls the temperature of the mixture. What other factor must be considered to maintain the asphalt viscosity required for effective mixing?

1. The quality of the aggregates
2: The gradation of the aggregates
3. The proper dryer temperature
4. Each of the above

6-17. In a test run during production of a paving mix, 52,530 pounds of mix was produced. Assume further that 27 sacks of mineral filler weighing 90 pounds each were added to the filler hopper to keep it level full while the trucks were being loaded. If the asphalt content by weight of the total mix is 2,889 pounds, what is the percent of mineral filler based on dry mix added to the paving mix?

1. 4.89 percent
2. 5.00 percent
3. 14.89 percent
4. 20.40 percent

6-18. Asphalt pumping adjustments are required to change the quality of asphalt discharge whenever major temperature changes occur.

6-19. Compared to the mixing principle of the batch mixer, the pugmill mixer differs in the method of

1. selecting an appropriate asphalt
2. mixing the material being propelled toward the discharge
3. controlling aggregate gradation
4. adjusting the mixing time

6-20. A pugmill's "live zone" is the net volume in cubic yards below a line extending across the top arc of the inside body shell radius, with shafts, liners, paddles, and tips deducted.

In answering items 6-21 through 6-23, select from column B the mixing time that is described in column A.

	A. Description of Mixing Time	B. Mixing Time
6-21.	Begins with the start of asphalt application and ends with opening of discharge gate	1. Wet mixing time 2. Total mixing time
6-22.	Begins when all combined aggregates are in mixer and ends with introduction of asphalt	3. Dry mixing time 4. Shortest mixing time
6-23.	Begins when all combined aggregates are in mixer and ends with the opening of discharge gate	

6-24. Which of the following factors governs the efficiency of mixing asphalts and aggregates?

1. Pitch of the mixing paddles
2. Arrangement of the mixing paddles
3. Speed of the mixer shafts
4. Each of the above

Learning Objective: Indicate functions of the components of a batch asphalt plant. Textbook page 5-65.

6-25. Which component of the batch asphalt plant contains aggregates that have been screened and stored by size?

1. Cold aggregate storage and feed
2. Dryer
3. Batching unit
4. Dust collector

6-26. The weigh-hopper on the asphalt plant of textbook figure 5-69 performs which of the following functions?

1. Measuring all sizes of aggregate
2. Holding the correct weight of each aggregate
3. Both 1 and 2 above
4. Measuring the amount of asphalt for each batch

6-27. By what means is the correct amount of asphalt delivered to the plant pugmill from the asphalt weigh bucket?

1. Metered valve release
2. Metered scale and valve release
3. An adjustable suction pipe

6-28. The blending of aggregates and asphalt within a batch asphalt plant is completed in the plant pugmill.

6-29. Due to the size of its opening, the discharge gate on the batch asphalt can do which of the following?

1. Limit the amount of fines that enter the haul vehicle
2. Discharge an entire batch without segregation of asphalt and aggregates
3. Eliminate the need for maintenance and parts replacement
4. Estimate the weight of asphalt in each batch

Learning Objective: Indicate steps taken in the inspection, adjustment, or operation of paving equipment. Textbook pages 5-65 through 5-69.

6-30. In the inspection of an asphalt distributor prior to paving operations, which of the following tasks is a checkpoint?

1. Setting of spray bars and nozzles
2. Operating condition of heaters and pumps
3. Calibration of tachometer and measuring stick
4. Each of the above

6-31. When checking a paver, the operator must see that the

1. steel wheels are straight across and free from grooves
2. automatic controls are properly adjusted
3. mat thickness and crown controls are adjusted properly
4. fasteners and strike-off surfaces are not worn excessively

6-32. The condition of each roller used on a project should be inspected to make sure of which of the following functioning operations?

1. It starts, stops, and reverses smoothly
2. Its total weight is within specified limits
3. Its scrapers, wetting pads, and vibrators are in good working order
4. All of the above

6-33. When dump trucks are used to transport hot plant mix over long distances, which of the following factors should be considered?

1. Insulation of truck beds
2. Tarpaulins to cover the mix during transport
3. Both 1 and 2 above
4. Condition of the screed heater

6-34. When bituminous materials are being heated, a foam-type fire extinguisher should be accessible.

6-35. Before attempting to spray bituminous material, personnel should be instructed to stand a minimum of how many feet clear of the spray bar?

1. 10 feet
2. 25 feet
3. 15 feet
4. 40 feet

6-36. Refer to textbook table 5-9. What is the suggested safe heating temperature for grade 120-150 asphalt cement used for distributor spray application?

1. 225° to 300°F
2. 254° to 325°F
3. 285° to 395°F
4. 295° to 405°F

6-37. Personnel engaged in asphalt processing operations should wear which of the following equipment or clothing?

1. Goggles
2. Safety hats and shoes
3. Loose fitting, heavy clothing
4. All of the above

6-38. When repairing, lubricating, or adjusting a moving part of an asphalt plant, you may remove the safety guard but only if the power is shut off.

6-39. Which member of a paving crew is responsible for insuring that all of the warning devices on paving equipment are in good operating condition?

1. The safety inspector
2. The operator
3. The crew leader

Learning Objective: Point out principles of site selection and preparation. Textbook pages 6-1 through 6-4.

6-40. Which of the following conditions is an advantage of using an existing pit or quarry?

1. Availability of facilities
2. Existence of haul and access roads
3. Easy-to-determine quantity of materials
4. Each of the above

6-41. It is desirable to locate a pit site near suitable haul roads.

In answering items 6-42 through 6-46, select from column B the preparatory work that matches the site requirement in column A.

A. Site Requirements

6-42. Determine the limits of the site, methods of excavation, and location of structures

6-43. Install facilities as early as possible, and dispose of surface water

6-44. Coordinate with excavation so the site is cleared continuously

6-45. Remove large trees and stumps

6-46. Dump the spoil in a remote area

B. Preparatory Work

1. Removing overburden
2. Clearing
3. Drainage
4. Making an operations plan

6-47. The maximum grade for access roads used by trucks is

1. 5 percent
2. 10 percent
3. 15 percent
4. 20 percent

6-48. When power shovels or clamshells are unavailable, a plain chute ramp is used for loading excavated materials onto trucks.

6-49. The width of the formation for a 9-foot-wide processing plant should be

1. 6 ft
2. 9 ft
3. 12 ft
4. 15 ft

6-50. When processing equipment is placed within a pit or quarry to insure safe operation, which of the following steps should be taken?

1. Position the equipment to reduce damage from blasting
2. Protect the equipment against the effects of dust by means of water sprays or the like
3. Install guardrails and protective shields
4. Each of the above

Learning Objective: Point out principles and methods of pit operations. Textbook pages 6-4 through 6-7.

6-51. Lines AA and BB of textbook figure 6-2 define the outer limits of the

1. excavation zone
2. entire pit
3. stripping zone
4. clearing zone

6-52. What type of equipment is working zone 2 of textbook figure 6-2?

1. Scraper
2. Dozer
3. Dragline
4. Power shovel

6-53. Which of the following types of equipment is especially suited for hillside deposit removal?

1. Scraper
2. Dozer
3. Power shovel
4. Front-end loader

6-54. Assume you are applying the layout and development techniques of textbook figure 6-3. Your loop traffic system should enable equipment operators to

1. drive loaded and unloaded trucks over the same roadways within the pit
2. turn around in the middle of the roadways
3. drive loaded and unloaded vehicles over routes that do not cross
4. select their own routes

6-55. When a power shovel is working against a pit face using the circular bench method, the operator must maintain a downgrade of

1. 10 percent or less
2. 12 percent
3. 15 percent
4. 20 percent

6-56. What factor limits the depth in which a straight line bench deposit can be excavated?

1. Elevation of the ground water table
2. Width of the deposit
3. Type of material being excavated
4. Traffic control layout

6-57. Which of the following pieces of equipment can be used to load stockpiled material into dump trucks?

1. Front-end loader
2. Bucket loader
3. Either 1 or 2 above
4. Dragline

Learning Objective: Point out principles and methods of quarry operations. Textbook pages 6-7 through 6-13.

6-58. Quarrying is defined as the process of extracting rock from its natural state and includes crushing and screening the rock.

6-59. Which of the following quarries is a type commonly used by the military?

1. Closed-face, multiple bench
2. Double-bench
3. Open-face, single-bench
4. Closed-face, single-bench

6-60. What factor determines the layout of a quarry where the rock formation is jointed?

1. Method of development
2. Depth of overburden
3. Direction of the rock formation

6-61. A single bench quarry is safer and more efficient to operate than a multiple bench quarry.

6-62. In the development of a triple bench quarry, which bench is worked first?

1. Lowest
2. Middle
3. Highest

6-63. Crushing and screening plants are operated to process materials for planned construction projects.

6-64. What component of the first-stage crushing unit is powered by a diesel engine?

1. Delivery conveyor
2. Jaw assembly
3. Feeder belt
4. Each of the above

6-65. What happens to the raw material that, because of its size, bypasses the jaw crusher chamber?

1. It is discarded
2. It is mixed with the crusher product
3. Either 1 or 2 above
4. It is stockpiled

6-66. Measured in inches, the product setting of the jaw crusher ranges from 1 1/2 to

1. 5
2. 2
3. 3
4. 4

6-67. What product setting on the roll crusher enables the secondary unit to operate as a "closed circuit" crushing system?

1. It is set at or slightly larger than the top screen opening size
2. It is set at or slightly less than the top screen opening size
3. It is set at or slightly larger than the bottom screen opening size
4. It is set at or slightly less than the bottom screen opening size

6-68. The actual production rate (TPH) of the secondary unit is usually determined by the capacity of the

1. roll crusher
2. jaw crusher
3. screens
4. hopper

6-69. Of the basic setups for a 75-TPH crushing plant, which should be used when the bulk of material from a gravel deposit is 3 inches in diameter or less?

1. Primary unit only
2. Secondary unit only
3. Primary and secondary units together
4. Jaw crusher only

Assignment 7

Pits and Quarries (continued) Well Drilling

Textbook Assignment, NAVEDTRA 10641-G: Pages 6-14 through 6-21 and 7-1 through 7-19

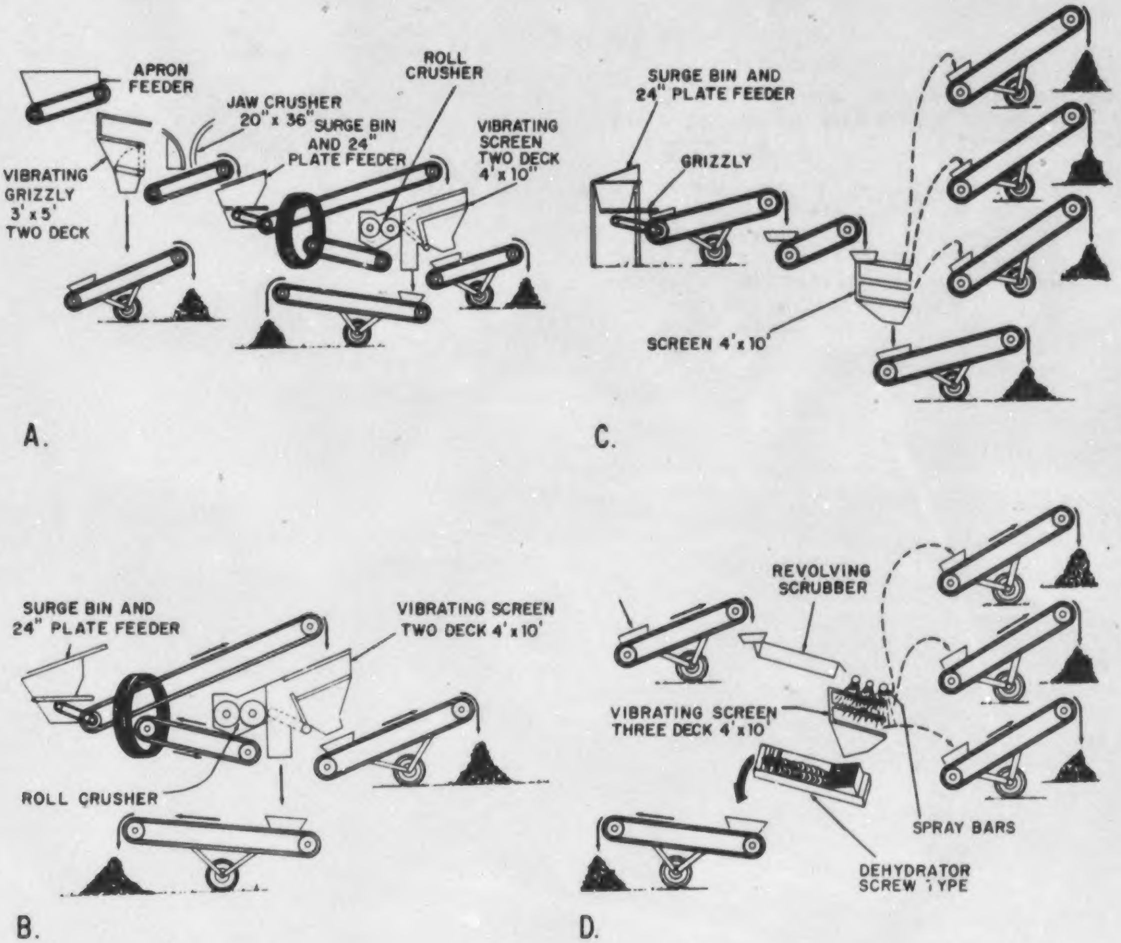
APRON FEEDER
JAW CRUSHER 20" x 36"
SURGE BIN AND 24" PLATE FEEDER
ROLL CRUSHER
VIBRATING SCREEN TWO DECK 4'x 10"
VIBRATING GRIZZLY 3'x 5' TWO DECK
A.
SURGE BIN AND 24" PLATE FEEDER
GRIZZLY
SCREEN 4'x 10'
C.
SURGE BIN AND 24" PLATE FEEDER
VIBRATING SCREEN TWO DECK 4'x 10'
ROLL CRUSHER
B.
REVOLVING SCRUBBER
VIBRATING SCREEN THREE DECK 4'x 10'
SPRAY BARS
DEHYDRATOR SCREW TYPE
D.

Figure 7A

Learning Objective: (continued)
Point out principles and methods of quarry operations.
Textbook pages 6-14 through 6-21.

- In answering items 7-1 through 7-3, refer to figure 7A.

7-1. Which plant setup produces two sizes of finished products?

1. A
2. B
3. C
4. D

7-2. Which plant setup is used when only screening is required?

1. A
2. B
3. C
4. D

7-3. Which plant setup is used for processing quarry material whose diameter is greater than 3 inches?

1. A
2. B
3. C
4. D

In answering items 7-4 through 7-7, select from column B the equipment arrangement that matches the function in column A.

A. Functions

7-4. Produces sand and gravel without crushing

7-5. Produces accurately sized material

7-6. Crushes a large percent of oversized materials

7-7. Produces a clean dehydrated sand

B. Equipment Arrangements

1. Primary unit, secondary unit, and washing and screening unit
2. Primary unit and secondary unit
3. Roll secondary unit and washing and screening unit
4. Washing and screening unit and screening unit

7-8. Less lead time is required to procure repair parts for crushing and screening equipment than for other kinds of construction equipment.

7-9. Equipment Operators and Construction Mechanics should maintain the crushing and screening units to prevent them from breaking down.

7-10. Putting off scheduled maintenance due to production demands tends to reduce production rates in the long run.

7-11. Blasting of quarry material that cannot be removed with construction equipment comes under the control of a qualified Blaster.

7-12. During quarry operations, an assigned Blaster is responsible for which of the following blasting tasks?

1. Carrying explosives and detonators and opening cases
2. Priming, loading, and stemming
3. Connecting blasting circuits and firing
4. All of the above

Learning Objective: Identify fundamentals of developing sources of ground water.
Textbook pages 7-1 through 7-3.

7-13. In which underground zone, if any, should a water well be developed?

1. Plant root
2. Saturation
3. Aeration
4. None

7-14. Which, if any, of the following belts in the zone of aeration produces usable quantities of water?

1. Intermediate belt
2. Capillary fringe
3. None

7-15. What is the name for the water contained in the zone of aeration?

1. Ground water
2. Soil water
3. Subsurface water
4. Surface water

7-16. The sand in the zone of saturation confined between two layers of clay can hold water and also allow it to flow. The clay is described as being able to

1. hold relatively little water
2. hold subsurface water only
3. prevent the flow of water
4. produce water in usable quantities

7-17. An artesian well is a source of fresh water flowing freely from an aquifer where the water pressure exceeds atmospheric pressure.

7-18. Which of the following rock formations is most likely to produce water in usable quantities?

1. Igneous
2. Sedimentary
3. Metamorphic

7-19. There is a good chance of recovering ground water at shallow depths in certain alluvial valleys and in which of the following topographical features?

1. Alluvial basins
2. Glacial outwashes
3. Alluvial fans
4. All of the above

7-20. When nothing is known of the water resources in a particular area, the existence of water-producing formations can be verified by which of the following means?

1. Exploratory drilling
2. Inspecting outcrops of rock formations
3. Studying maps and documents
4. Each of the above

7-21. What type of well can supply fresh water from a source 50 to 1500 feet underground?

1. Dug
2. Bored
3. Driven
4. Drilled

Learning Objective: Recognize operating principles and techniques of drilling wells by the rotary and percussion methods.
Textbook pages 7-3 through 7-18.

7-22. Spudding is the preferred method of drilling wells in

1. sandy loose soil
2. unconsolidated river gravel
3. consolidated formations
4. quicksand

7-23. During rotary drilling, a rapid yet smooth penetration of the drill bit is an indication that the bit is entering a

1. clay formation
2. formation of fine sand
3. bed of gravel

7-24. During the course of drilling for water, clues that indicate the composition of each formation penetrated come from changes in the

1. depth of drilling
2. speed of drilling
3. diameter of the drilled hole
4. amount of water obtained

7-25. During the drilling of a well by the rotary process, cut material is raised to the surface with pressurized air.

7-26. Which component of a rotary well-drilling rig is connected to the top joint of the drill pipe?

1. Hoisting plug
2. Kelly
3. Water swivel
4. Drill collar

7-27. Which of the following components of the rotary well-drilling rig controls the rate of feed to the drilling bit?

1. Kelly drum brake
2. Hoist drum
3. Drill collar
4. Rotating table

In answering items 7-28 through 7-30, select from column B the rotary well-drilling rig accessory that performs the function in column A.

A. Functions

7-28. Enables the bit to drill a straight hole

7-29. Allows the drill pipe to turn freely while hoisted

7-30. Holds the drill pipe securely during joint addition or removal

B. Accessories

1. Set of slips
2. Drill collar
3. Hoisting plug
4. Kelly sub

7-31. When installed, drill casing will keep the walls of a well hole from getting bigger.

7-32. Which of the following is a situation that calls for the drill casing to be washed down to the bottom of a well hole?

1. Being welded instead of threaded, the casing cannot run into the hole
2. The casing cannot run down because the hole is caved in
3. The casing has to be planted on a firm foundation

7-33. In the operation of the rotary drilling rig, what factors work together to prevent the walls of the drill hole from collapsing when the cut material is washed to the surface by a mixture of mud and water?

1. The filtering action of the coarse material in the settling pit
2. The fluid's weight and viscosity and the fluid's plastering action on the wall of the well hole
3. The action of suspended local mud in the fluid and the additional weight of the fluid due to its content of suspended clay
4. The suspension of cuttings in the settling pit and the spiraling of fluid against the wall of the drill hole

7-34. Of the crewmembers operating the rotary well-drilling rig, who has the responsibility for carrying out the overall drilling program?

1. Project supervisor
2. Tool pusher
3. Driller
4. Derrick hand

7-35. Personnel engaged in well-drilling operations should observe which of the following safety measures?

1. Wear tight fitting clothes while working around moving machinery
2. Wear gloves when handling cables or metal parts
3. Wear safety shoes and hard hats
4. All of the above

7-36. Which type of rotary drilling rig must be leveled before drilling operations begin?

1. Skid-mounted
2. Truck-mounted
3. Trailer-mounted
4. Each of the above

7-37. The settling pit may be cleaned of cuttings while a drill pipe is being changed or during drilling.

7-38. What is considered the normal quantity of water needed to support an 8-hour shift of rotary well-drilling?

1. 100 to 500 gal
2. 500 to 750 gal
3. 750 to 1000 gal
4. 1000 to 4000 gal

7-39. What type of drill bit is used for drilling through a moderately hard surface formation with a rotary rig?

1. Pilot
2. Roller
3. Fishtail
4. Three-way

7-40. The next step in the procedure of setting up the truck-mounted rotary well-drilling rig, after it has been leveled, is to raise the drilling mast and lock it in.

7-41. After the well hole has been drilled the length of the kelly, what accessory is placed to keep the well from caving in from the surface?

1. Turntable
2. Surface casing
3. Drill collar
4. Set of slips

7-42. What material is used to reduce a possible seizure of the drill pipe with the kelly during drilling operations?

1. Drilling lubricant
2. Petroleum jelly
3. Wicking
4. Fish oil

7-43. After you have reached the desired drilling depth and have pulled the drill pipe, your next step in the drilling process is to

1. cap off the hole
2. place the screen casing
3. grout the well head
4. remove most of the fines

7-44. What should be done during a drilling operation to compensate for caving caused by excessive fluid loss in soil composed of sand and gravel?

1. Add more fluid
2. Add sand and gravel mixture
3. Replace the lost fluid with sand
4. Replace the lost fluid with mud

7-45. One method of regaining a loss of circulation that takes place during well drilling is to circulate the cuttings away from the drill bit with plenty of water.

7-46. In straight-hole drilling, what is the maximum allowable diameter of the drill pipe hole?

1. Two and one-half times the diameter of the drill pipe
2. Twice the diameter of the drill pipe
3. One and one-half times the diameter of the drill pipe
4. One and one-fourth times the diameter of the drill pipe

7-47. Undue wear of the drill pipe is an indication of a crooked drill hole.

7-48. During a drilling operation, the drill pipe may stick due to which of the following causes?

1. A mud pump of inadequate capacity
2. Allowing the drill pipe to stop and remain stationary in the hole
3. Mud balling up around the drill collar and bit
4. Each of the above

7-49. The drill pipe of your rotary well-drilling rig becomes stuck with drill cuttings that have accumulated in the hole. How can you remedy the situation?

1. Pull upward on the pipe with jacks
2. Circulate heavy mud while trying to turn the pipe
3. Pour oil along the sides of the pipe
4. Pull upward on the pipe and circulate clear water around it

7-50. When the drill pipe sticks while drilling through a shale formation, which of the following methods of loosening a pipe should be tried?

1. Keeping strain on the pipe only
2. Spotting oil along the portion of the pipe that is stuck while keeping a strain on the pipe
3. Circulating heavy mud around the pipe

7-51. Which of the following is a practical use of a fishing tool?

1. Recovery of a twisted-off drill pipe
2. Recovery of a wrench that falls into the drill hole
3. Recovery of a drill pipe that falls into the drill hole
4. Each of the above

7-52. Which well-drilling tool, if any, is equipped with a watertight coupling between the drill pipes?

1. Circulating-slip overshot
2. Tapered overshot
3. Die overshot
4. None

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7-53. The 3-inch swab used in rotary well-drilling operations to clean the screen or strainer at the bottom of the casing functions by means of

1. a hollow mandrel fitted with a ball valve
2. two cup-type pistons enclosed in a wire basket
3. a two-piece piston which serves as a check valve
4. a ball valve which closes on the downstroke of the piston and opens on the upstroke

7-54. The main component of a percussion-type drilling rig is its

1. spudder
2. bailer
3. sand pump
4. sand reel

7-55. What drilling tool furnishes the weight needed by the tool string of a percussion drill rig?

1. Jar
2. Drive clamp
3. Drill stem
4. Bailer

7-56. The four-wing or star bit is the best general-purpose spudding tool.

7-57. Which of the following tools are used to loosen bits stuck in a well hole when hard rock is being drilled with the spudding rig?

1. Drive clamps
2. Swivel sockets
3. Rope savers
4. Drilling jars

7-58. What device in the drilling line of a percussion rig, can eliminate some of the causes of out-of-round holes?

1. Drill stem
2. Bailer link
3. Rope saver
4. Swivel socket

7-59. Which of the following is a step in the procedure for getting a spudding rig ready to drill?

1. Swing the tools on the mast, hanging them directly down the center
2. Place the rope saver on the end of the swivel socket
3. Set the tools on the ground, marking the drilling spot
4. Each of the above

7-60. In most hard-rock drilling with the spudder, what is (a) the stroke length and (b) the tool weight that will produce the best drilling results?

1. (a) 24 in. and (b) 1000 lb
2. (a) 24 in. and (b) 1700 lb
3. (a) 32 in. and (b) 1000 lb
4. (a) 32 in. and (b) 1700 lb

7-61. Cuttings that result from drilling a well hole with a spudder are removed by means of

1. a dart-valve bailer or sand pump
2. heavy mud
3. a drilling jar
4. air pressure

7-62. Which of the following devices enables the sand line to be attached to either the bailer or sand pump?

1. Swivel socket
2. Bailer link
3. Rope saver
4. Drive clamp

7-63. The bit used on your percussion drilling rig breaks off in the hole. Examination of the markings on the friction socket indicates that the socket went down beside the bit and not over it. What fishing tool should you use to attempt to straighten the bit?

1. Jar bumper
2. Wall hook
3. Spud
4. Combination socket

7-64. In percussion drilling, which of the following fishing tools should be used to recover the bailer if the sand line breaks?

1. Jar bumper
2. Rope grab
3. Friction socket
4. Wall hook

Learning Objective: Indicate principles of developing and completing water wells. Textbook pages 7-18 and 7-19.

7-65. The setting of the casing and screens is the first operation in developing a well after the borehole is drilled.

7-66. In completing a developed well, the space between the well wall and casing is cemented to

1. trap the drilling mud below the water table
2. keep surface water or contaminated water from seeping into the aquifer
3. prevent the drilling mud from solidifying

7-67. To accommodate any specified pump, the maximum casing diameter of a drilled well should be less than one nominal size larger than the pump.

7-68. The efficiency of a completed water well that taps a sand and gravel formation depends largely on the

1. type of grouting used to cement the space between the well wall and casing
2. size of the well screen slot openings
3. type of casing used to prevent collapse of the borehole walls
4. extent to which the formation is compacted

7-69. Which of the following steps, if any, should be taken to control the water that enters a well at the rate of 0.2 foot per second?

1. Decrease the length of the screen
2. Decrease the intake diameter of the screen
3. Increase the intake diameter of the screen
4. None

Assignment 8

Construction and Automotive Pool Management

Textbook Assignment, NAVEDTRA 10641-G: Pages 8-1 through 8-23

Learning Objective: Identify practices in setting up and managing an equipment/transportation pool. Textbook pages 8-1 through 8-9.

8-1. In selecting a site for a construction/automotive pool, which of the following factors should you consider?

1. Adequacy of the site's drainage system
2. Nearness of the site to the center of activity
3. Capacity of the site for equipment parking and expansion
4. All of the above

8-2. That part of the transportation pool designated for the parking of heavy equipment should be equipped with a loading ramp.

8-3. What type of surface is generally used for a transportation pool at an advanced base?

1. Concrete
2. Asphalt
3. Gravel
4. Packed earth

8-4. When the equipment pool is located at an advanced base in a combat zone, you should disperse vehicles to

1. lessen possible damage from attack
2. present large targets
3. control work elements
4. handle servicing of the vehicles

8-5. The basic objectives of equipment pool management are obtaining safe and serviceable equipment and insuring maximum service life of the equipment.

● In answering items 8-6 through 8-8, use the following alternatives.

1. Planning and scheduling shopwork
2. Organizing
3. Coordinating jobs
4. Controlling work input

8-6. Applying equipment pool management techniques to accomplish planned objectives is effective in

8-7. Sources of information that save time and effort in running an equipment pool are useful in

8-8. Maintaining a tickler file to help insure the availability of equipment is an effective means of

8-9. Equipment downtime can be minimized by controlling the operation and maintenance of equipment.

8-10. An input of operational data and performance standards should enable you to determine the basic causes of operational and maintenance variances in pool equipment usage.

8-11. How can you be sure pool equipment remains safe and in serviceable condition?

1. By establishing an equipment checkpoint in the pool area
2. By establishing and carrying out an equipment preventive maintenance schedule
3. By allowing only qualified drivers to operate equipment
4. By allowing only an 8-hour equipment operating period

8-12. How can you tell whether or not a truck is safe and serviceable?

1. Check to see that truck components are properly tightened
2. Inspect all truck components for signs of improper lubrication
3. Check to see that no truck component is worn excessively
4. All of the above

8-13. A dump truck stalls occasionally at intersection stops. What shall the operator of this truck do?

1. Get another dump truck
2. Report the condition to the supervisor
3. Execute NAVFAC 9-11240/13
4. Operate the dump truck at half its capacity

8-14. With the exception of tire and battery repair or replacement, about how much of the work done by a maintenance shop can be planned and scheduled?

1. 55%
2. 65%
3. 75%
4. 85%

8-15. At which of the following times should qualified automotive inspection personnel inspect vehicles for safety and serviceability?

1. The time a scheduled Type "A" is performed
2. 6-month intervals or less, or 6,000 miles, whichever occurs first
3. The time a scheduled Type "B" is performed
4. The time a scheduled Type "C" is performed

8-16. How many working days serve as a basis for establishing the PM schedule for maintaining pool equipment?

1. 10
2. 20
3. 30
4. 40

8-17. Which of the following are samples of component collateral equipage items?

1. Water pumps
2. Starter ropes
3. Fuel cans
4. Fire extinguishers

8-18. As equipment pool supervisor, you can maintain control over collateral equipage by doing which of the following?

1. Keeping an accurate inventory of the equipage
2. Keeping a correct listing of the equipage
3. Getting the operator or crew leader to sign for checked-out equipage
4. Each of the above

8-19. Extra and obsolete collateral equipage is usually stored with the basic machine.

8-20. As an equipment pool supervisor, you are responsible for seeing that the forms and records are indexed in accordance with

1. NAVFAC P-304
2. SECNAV Instruction 5210.11 series
3. NAVFAC P-103

In answering items 8-21 through 8-24, select from column B the identification code for the standard subject in column A.

	A. Standard Subjects	B. Identification Codes
8-21.	Automotive equipment	1. 11261
		2. 11240
8-22.	Heavy equipment	
		3. 11262
8-23.	Weight-handling equipment	4. 11260
8-24.	Construction-type equipment	

8-25. When ordering supplies of fuel and lubricants for a forthcoming deployment, you should submit which of the following reports or documents?

1. Daily Fuel Issue Report
2. Monthly Fuel Usage Data Report
3. Requisition and Invoice/Shipping Document
4. Single Line Item Consumption/Management Document (manual)

8-26. Which of the following forms does NOT carry an identification number?

1. Operator's Inspection Guide and Trouble Report
2. Job Order Progress Record Sheet
3. Operator's Daily PM Report
4. Requisition and Invoice/Shipping Document

8-27. You can help keep track of the status of materials by maintaining a

1. Daily Man-Hour Report
2. Materials Expended Record
3. Job Order Progress Record Sheet
4. Equipment/Transportation Status Board

8-28. Which of the following records or reports shows where all pool equipment is located?

1. Job Order Progress Report
2. Daily Man-Hour Report
3. Materials Expended Record
4. Equipment Status Board

Learning Objective: Explain the duties and responsibilities of a license examiner.
Textbook pages 8-9 through 8-21.

8-29. As a license examiner, you are responsible for doing which of the following?

1. Administering license examinations
2. Licensing operators
3. Training and instructing license applicants
4. All of the above

8-30. In which of the following cases, if any, would the driving privilege be extended to a person who holds an expired government operator's license?

1. Sudden illness
2. Transfer of duty station
3. Combat duty
4. None

8-31. For which of the following reasons may a license examiner refuse to issue an operator's license?

1. Birthplace of the applicant
2. Physical defect of the applicant
3. Marital status of the applicant
4. Religious belief of the applicant

8-32. As a license examiner, you may impose testing requirements that conflict with those in P-300 or P-404.

8-33. Refer to textbook figure 8-9. By what authority can the privilege of operating a government vehicle be denied if an applicant does NOT provide the information requested on NAVFAC 11240/10?

1. SECNAV Instruction 5210.11
2. Chapter 3 of P-404
3. Chapter 930 of the Federal Personnel Manual
4. Title 40, U.S. Code 471

8-34. The Application for Construction Equipment Operator License is usually endorsed by both the applicant's sponsor and commanding officer.

8-35. In which, if any, of the following cases may naval personnel be extended the privilege of operating a general-purpose vehicle whose gross vehicle weight is 10,000 pounds or less without taking a Navy license examination?

1. He or she has a valid state operator's license for the vehicle
2. He or she has been recommended by the commanding officer
3. He or she has completed a driver's training course
4. None

8-36. After completing Standard Form 47, an operator's license applicant must take a physical examination if assigned to haul explosives.

8-37. Which of the following is NOT included in written tests given to license applicants?

1. Knowledge of local, state, and battalion regulations
2. Accident reporting procedures
3. Insurance requirements for operation of naval automotive or construction equipment
4. Operator's responsibilities for inspection and preventive maintenance

8-38. In the process for obtaining a Navy operator's license, what is the next step after the written test is passed?

1. Physical examination
2. Performance Qualification Test
3. Driver's Skill Test
4. Each of the above

8-39. What type of license is issued to an applicant qualified to operate construction equipment?

1. Standard Form 47
2. Standard Form 46
3. NAVFAC Form 11260/10
4. NAVFAC Form 11260/2

8-40. A materials-handling equipment operator carries what type of license?

1. Standard Form 46
2. NAVFAC Form 11260/10
3. NAVFAC Form 11260/2
4. NAVSUP Form P-284

8-41. Which of the following is a restriction noted on the license of an operator of a 5-ton dump truck?

1. Wearing of gloves
2. Wearing of glasses
3. Wearing of a hard hat

8-42. The license to operate a Navy vehicle is valid for at LEAST five years.

8-43. Which of the following entries on a Construction Equipment Operator's License, NAVFAC Form 11260/2, indicates its expiration date?

1. Card number
2. Date issued
3. Operator's birth date
4. Equipment type

8-44. By completing a NAVFAC Form 11260/03, the license examiner has a complete record of a construction equipment operator's qualifications.

8-45. In license upgrading, the examiner must give an operator a qualifying test on the equipment to which the license is being upgraded.

8-46. How does an operator proceed to replace a lost license?

1. Apply for retesting
2. Submit a new license application
3. Have the examiner verify that the original license was issued
4. Have the original license upgraded

8-47. Who may suspend an operator's license for cause?

1. Officer in charge
2. Equipment officer
3. Commanding officer
4. Each of the above

8-48. The revoked license of an operator can be restored by reexamination and reevaluation of the operator.

8-49. Who supervises the training given an applicant before he or she is issued an operator's license?

1. License examiner
2. Equipment officer
3. Safety officer
4. Each of the above

8-50. In which of the following cases are trainees NOT required to have a training license?

1. When operating Navy equipment as part of their training at an NCTC
2. When accompanied by a qualified instructor
3. When operating Navy equipment in a controlled training situation

8-51. Which of the following subjects must a license applicant study in a course of instruction?

1. Accident reporting procedures
2. Safe driving practices
3. Equipment limitations
4. All of the above

8-52. The unauthorized use of a Navy vehicle would expose military personnel to trial by court martial.

Learning Objective: Recognize fundamentals of environmental pollution control.
Textbook pages 8-22 and 8-23.

8-53. The term "environmental pollution" applies to the pollution of which of the following substances?

1. Air
2. Water
3. Soil
4. All of the above

8-54. Carbon monoxide, sulfur oxides, and unburned hydrocarbons are fuel components and combustion products which pollute the

1. air only
2. water only
3. soil only
4. air, water, and soil

8-55. The most effective way to combat pollution caused by exhaust emissions is to

1. filter the exhaust
2. return the unburned gases to the carburetor
3. keep the engine well tuned
4. use a filter scrubber system

8-56. If NOT taken care of immediately, an oil spill may cause which of the following problems?

1. Fire hazard
2. Fish kill
3. Contaminated water supply
4. All of the above

8-57. Which of the following are the largest contributors to water pollution?

1. Automotive vehicles
2. Ships and tankers
3. Accidental spills
4. Offshore oil wells

8-58. Which of the following practices helps in the fight against water and soil pollution?

1. Collecting and properly disposing of spent crankcase oil
2. Sprinkling absorbent material on spilled oil
3. Providing drip pans to catch unavoidable spills
4. Each of the above

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Assignment 9

Miscellaneous Construction Equipment

Textbook Assignment, NAVEDTRA 10641-G: Pages 9-1 through 9-22

Learning Objective: Point out principles of operating an aggregate and cement batching plant. Textbook page 9-1 only.

9-1. What step does the batch plant operator take to obtain a specific weight of aggregate used in a mix?

1. Position the weight on the weigh box
2. Position the weight on the beam scale
3. Adjust the discharge gates on the storage hoppers
4. Adjust the quality control unit

9-2. Who is responsible for producing the batch plant mixes as specified by project requirements?

1. Quality control technician
2. Builder supervisor-inspector
3. Equipment operator
4. Planning and estimating officer

Learning Objective: Point out techniques of operating and maintaining a concrete transit truck. Textbook pages 9-2 through 9-7.

- In answering items 9-3 through 9-6, refer to textbook figure 9-3.

9-3. Which lever allows the operator to control the direction of drum rotation?

1. 1
2. 2
3. 3
4. 4

9-4. Which lever sets the mixer speed?

1. 1
2. 2
3. 3
4. 4

9-5. Which lever is used to shift drum rotation?

1. 1
2. 2
3. 3
4. 4

9-6. Which lever allows the operator to speed up the charging of the drum?

1. 1
2. 2
3. 3
4. 4

9-7. Water and cement comprise nearly what percentage of the mix transported by the transit mixer?

1. 65 to 80%
2. 50 to 70%
3. 20 to 35%
4. 10 to 15%

9-8. In shrink mixing of concrete, where does the mixing process begin?

1. At the plant
2. In the transit mixer shortly after it leaves the batch plant
3. In the transit mixer just before it reaches the jobsite
4. At the jobsite

9-9. What type of concrete mixer operation calls for all materials EXCEPT water to be loaded into the truck mixer drum at the bulk plant?

1. Central mixing
2. Jobsite mixing
3. Transit mixing
4. Shrink mixing

9-10. The most important step in mixing concrete is charging the mixer.

9-11. What effect, if any, does overmixing have on concrete being transported to a jobsite?

1. The temperature of the concrete is lowered
2. The concrete is weakened
3. The quality of the concrete is improved
4. None

9-12. Assume that you are hauling concrete to a jobsite that requires 30 minutes travel time one way and you leave the plant with the drum operating at a mixing speed of 5 rpm. After how many minutes should you change the drum speed to 2 rpm agitating speed?

1. 5
2. 7
3. 10
4. 14

9-13. After a transit mixer is charged for jobsite mixing, the drum should be operated at a speed of approximately

1. 5 rpm
2. 7 rpm
3. 14 rpm
4. 16 rpm

9-14. Intermittent discharging of concrete from a transit mixer should be controlled by using the

1. engine throttle
2. engine clutch
3. mixer control lever
4. mixer sealing door

9-15. After the mix is discharged at a jobsite, what happens to the water that is used to clean the inside of the mixer drum?

1. It remains in the drum and the amount is figured into the next load
2. It is discharged at the jobsite
3. It is discharged into a holding tank
4. It is siphoned off during the return trip

9-16. To prevent concrete from sticking to them, the structural members of a transit mixer should be treated with

1. grease
2. paraffin and diesel oil
3. hypoid gear oil
4. engine oil

9-17. Which of the following components allows the operator to hold the chute in the desired position when discharging concrete from a transit mixer?

1. Unilever
2. Mixer control lever
3. Hydraulic chute hoist
4. Friction lock chute brake

9-18. Daily services in maintaining the transit mixer include cleaning, washdown, and lubrication.

9-19. The type of lubricant used in the worm gear drive of the transit mixer is

1. compound steam cylinder oil
2. hypoid gear oil
3. chassis grease
4. engine oil

9-20. Before making a drum chain adjustment, which of the following steps should you take?

1. Disengage the engine clutch
2. Move the unilever to neutral
3. Secure the mixer engine
4. Apply the friction brake lock

Learning Objective: Point out principles and techniques of operating a slip-form paver.
Textbook pages 9-7 through 9-10.

9-21. Which of the following is an advantage of laying down concrete with a slip-form paver?

1. Quality of the concrete is improved
2. Overmixing the concrete is avoided
3. Form-riding equipment or paving forms are eliminated
4. Temperature of the concrete is unaffected

9-22. In laying down concrete with a slip-form paver, how can you insure that the concrete slab will have a smooth, uniform surface?

1. Place the concrete on an accurately graded base
2. Place the concrete on a well-compacted base
3. Lay down concrete of uniform consistency
4. All of the above

9-23. In which order should the listed components of the slip-form paver be used during operation?

A. Extrusion plate
B. Burlap drag
C. Finishing belt
D. Strike-off screw
E. Beam vibrator
F. Tamping bar

1. A, C, E, F, B, D
2. A, E, F, C, B, D
3. D, E, F, A, C, B
4. D, E, F, B, C, A

9-24. Which of the following factors usually governs the production rate of a slip-form paver?

1. Condition of the base course
2. Amount of concrete placed in front of the paver
3. Speed of the paver
4. Each of the above

9-25. Which lever does the operator use to raise or lower the strike-off screw assembly?

1. Screw lever
2. Leveling lever
3. Clutch control lever

9-26. The function of the DC supply voltmeter on the operator's control panel is to measure the

1. voltage at each track
2. voltage at the panel
3. speed of each track
4. forward speed of the paver

9-27. When the paver is moved to another jobsite, which of the following controls provides a means of selecting its speed?

1. Clutch control
2. Traction speed selector
3. Directional selector

Learning Objective: Describe principles and techniques of maintaining pile hammers and power earth augers.
Textbook pages 9-11 through 9-18.

9-28. Of the following types of pile hammers, which uses the power drive to lift the ram during piledriving?

1. Drop
2. Single-action pneumatic
3. Double-action pneumatic
4. Diesel

9-29. What type of pile hammer is generally used to drive lightweight piles into average density soil?

1. Drop
2. Double-action pneumatic
3. Single-action pneumatic
4. Diesel

9-30. The pneumatic pile hammer drives piles about twice as fast as does a diesel hammer of comparable size and weight.

9-31. Compressed air trapped within a diesel pile hammer creates a preloading force upon which of the following parts?

1. Pile
2. Anvil
3. Drive cap
4. All of the above

9-32. The diesel pile hammer is stopped by which of the following operations?

1. Releasing the trip mechanism
2. Disengaging the fuel pump cam
3. Turning off the ignition switch
4. Locking the piston in its upper position

9-33. What part or parts of the diesel pile hammer must be checked for cleanliness every day the hammer is operated?

1. Bolts and nuts
2. Ram and anvil
3. Fuel pump check valve
4. Drive cap lashing cables

9-34. The power earth auger is capable of boring holes as large as 20 inches in diameter and as deep as how many feet?

1. 5
2. 7
3. 9
4. 11

9-35. The power earth auger is capable of boring vertically downwards only.

9-36. One purpose of the largest instrument shown in textbook figure 9-11 is to

1. indicate the amount of fuel in the tank
2. indicate the battery charging rate
3. measure the coolant temperature
4. measure the engine speed

● In answering items 9-37 and 9-38, refer to textbook figure 9-12.

9-37. Which lever starts the boring action of the auger after it has been raised and placed in the correct vertical position?

1. Auger clutch shift lever
2. Elevating valve lever
3. Feed valve lever
4. Leveling valve lever

9-38. Which of the following control levers is used to keep the auger shaft plumb from side to side to ground?

1. Elevating valve lever
2. Feed valve lever
3. Leveling valve lever
4. Each of the above

● In answering items 9-39 and 9-40, refer to textbook figure 9-13.

9-39. If the earth auger engine fails to start after cranking for more than 30 seconds, you must wait at LEAST one minute for the starter to cool before cranking again.

9-40. In starting the earth auger engine, you pull the choke control lever to the run position before turning on the ignition switch.

9-41. Which of the following is NOT a step in the procedure for starting the earth auger engine?

1. Performing routine prestart checks
2. Placing all auger controls in neutral
3. Elevating the auger shaft
4. Opening the fuel and hydraulic oil shutoff valves

9-42. To raise the auger shaft to the vertical position and to plumb it, the transmission of the earth auger should be in

1. neutral
2. second gear
3. third gear
4. fourth gear

9-43. How many minutes should you allow for the auger gears to warm up before attempting to drill?

1. 5
2. 10
3. 15
4. 20

9-44. What lever, shown in textbook figure 9-14, is used to tilt the auger shaft to the left or right?

1. Feed valve lever
2. Elevating valve lever
3. Leveling valve lever

9-45. You should use support jacks under the earth auger when drilling in

1. sand
2. hardpan or rocky soil
3. clay

9-46. The proper procedure for clearing the auger after it is loaded with dirt is to

1. raise the auger, disengage the clutch, push the hand throttle forward, then engage the clutch again to rotate the auger
2. disengage the clutch, push the hand throttle forward, then raise the auger and engage the clutch to rotate the auger
3. disengage the clutch, raise the auger and push the throttle forward at the same time, then engage the clutch to rotate the auger
4. push the hand throttle forward, disengage the clutch, raise the auger, then engage the clutch to rotate the auger

9-47. After disengaging the engine clutch and shifting the transmission into neutral, which of the following steps should you take to stop the earth auger engine?

1. Release the throttle lever and push it to the top
2. Allow the engine to idle for 5 minutes
3. Turn off the ignition switch
4. Each of the above

9-48. The coverings placed over unfilled bored holes should be adequate to support the weight of equipment or crewmembers.

9-49. The auger shaft of a truck-mounted earth auger should be positioned for travel when the auger is secured.

9-50. On earth augers that operate daily, which of the following are maintenance checkpoints?

1. Loose bolts and nuts and worn parts
2. Battery and coolant levels
3. Fuel and lube oil levels
4. All of the above

Learning Objective: Describe the procedure for operating a steam cleaner.
Textbook pages 9-19 and 9-20.

9-51. When operating the portable steam cleaner, which component must you always keep open?

1. Fuel valve
2. Pump switch
3. Water valve
4. Steam gun valve

9-52. With the burner switch turned on and the fuel valve open, how long should it take to ignite the fuel?

1. Less than 2 minutes
2. 2 1/2 minutes
3. 3 minutes

9-53. Before the steam cleaner can clean effectively, its steam pressure should be in the range of

1. 15 to 25 psi
2. 30 to 55 psi
3. 60 to 100 psi
4. 110 to 120 psi

9-54. When you are stopping the steam cleaner after having used it, which of the following is an indication that it is time to turn off the pump switch?

1. Hot water running from the shutoff valve
2. Cold water running from the water valve
3. Hot fuel entering the fuel valve
4. Cold water flowing from the steam gun

9-55. Which of the following is a safety control on the steam cleaner that can be adjusted to a setting lower than that preset at the factory?

1. High temperature control
2. Low temperature control
3. Relief valve

9-56. Other than LIME OUT, what material can be used to remove deposits from the steam cleaner?

1. Soda ash
2. Chlorine
3. Muriatic acid

Learning Objective: Describe the method of rating materials-handling equipment and point out safe practices in operating forklift trucks.
Textbook pages 9-21 and 9-22.

9-57. The ability of a forklift truck to lift a load depends upon which of the following factors?

1. Weight of the load
2. Length of the load
3. Both 1 and 2 above
4. Weight of the forklift

9-58. The capacity of a forklift truck is stated in which unit of measure?

1. Foot-pound
2. Inch-pound
3. Pound-foot
4. Pound-inch

9-59. A forklift truck is rated 6,000 pounds at 28 inches, and measures 20 inches from the heel of the forks to the center of the front axle. What is the capacity of this truck?

1. 156,000 foot-pounds
2. 248,248 foot-pounds
3. 288,000 inch-pounds
4. 288,288 inch-pounds

9-60. Assume the forklift truck of item 9-59 will be used to lift weight that is distributed uniformly on a 50- by 68-inch pallet. The maximum weight placed on this pallet should be

1. 6,400 lb
2. 6,208 lb
3. 5,800 lb
4. 4,460 lb

9-61. To safely transport material with a forklift, the operator should position the mast so it is

1. vertical or tipped forward
2. vertical or tilted backward
3. tipped forward only

9-62. Overhead safety guards are NOT required on forklift trucks if they interfere with freedom of movement of operators.

9-63. Which, if any, of the following is an acceptable method of increasing the capacity of a forklift truck?

1. Adding counterweights to the rear axle assembly
2. Attaching counterweights to the overhead safety guard
3. Increasing tire pressure
4. None

9-64. What type of pallet must be used for hoisting personnel with a forklift?

1. Cargo pallet
2. Special pallet having guard rails on the sides
3. Utility pallet
4. All-purpose pallet

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